NASA CR-111835

LOW-COST FABRICATION METHOD FOR ABLATIVE HEAT SHIELD PANELS FOR SPACE SHUTTLES

By Harry T. Abbott

Prepared under Contract No. NAS1 - 9945
BRUNSWICK CORPORATION
TECHNICAL PRODUCTS DIVISION
Lincoln, Nebraska

for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

NASA CR-111835

LOW-COST FABRICATION METHOD FOR ABLATIVE HEAT SHIELD PANELS FOR SPACE SHUTTLES

By Harry T. Abbott

Prepared under Contract No. NAS1 - 9945
BRUNSWICK CORPORATION
TECHNICAL PRODUCTS DIVISION
Lincoln, Nebraska

for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FOREWORD

This report has been written in compliance with the statement of work for Contract NAS1-9945. The work reported on herein was carried out at Brunswick Corporation, Technical Products Division, Lincoln, Nebraska. Mr. C. M. Pittman, of the Materials Division Langley Research Center, Hampton, Virginia, was NASA Contract Monitor for the program.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LOW-COST FABRICATION METHOD FOR ABLATIVE HEAT SHIELD PANELS FOR SPACE SHUTTLES

By Harry T. Abbott
Brunswick Corporation
Technical Products Division

SUMMARY

Space Shuttles will require a reliable, low-cost thermal protection system to survive the re-entry environment. Replaceable ablative panels, prefabricated for attachment to the external surface of the vehicle, can adequately provide the necessary protection.

This report describes the development and application of a low-cost compression molding process for this type of ablative panel. Flat and curved panels of four different ablative compositions were fabricated. The report presents detailed fabrication procedures, material costs, fabrication hours for all processes, costs of fabricated panels, and estimated costs for various panel sizes, shapes and quantities.

INTRODUCTION

Ablative heat shields are a proven and reliable thermal protection system for re-entry vehicles. If, however, an ablative heat shield is to be used on a re-useable logistic vehicle, the heat shield must be replaced after each flight. These types of heat shields have been very expensive on vehicles flown to date.

The objectives of the work scope reported herein was to develop a low-cost method of fabricating replaceable ablative heat shield panels, demonstrate the method through actual fabrication of panels, and project production costs. This report summarizes and documents the work accomplished in compliance with NASA Contract NAS1-9945.

The overall objectives were accomplished by subdividing the task into three steps as follows:

(1) Define a minimum cost method for fabricating flat and curved ablative shield panels

(2) Commit such process to the fabrication of specifically defined prototype panels, using the four contract-defined syntactic foam compositions

(3) Provide estimates for a complete set of various quantities, shapes, and sizes of ablative shield panels relating to a single flight, 10 flights, and 100 flights.

These three steps led to one further consideration relative to improvements possible which will be covered as a separate item.

The reporting against each of the above steps will be presented under the following sub-sections:

1. Panel Fabrication Evaluations

    1.1 Ablative Materials Evaluations

    1.2 Sub-scale Process Development

2. Panel Fabrication

3. Projected Process Improvements

4. Cost Projections

PROCESS DEVELOPMENT
AND
PANEL FABRICATION

Section 1
Panel Fabrication Evaluations

This section outlines the evolution and reasons for the process chosen for ablative panel fabrication. It provides an item-by-item explanation of sub-scale tests and test results relating to the various materials and process parameters necessary for successful panel fabrication.

<u>1.1 Ablative material evaluations</u>. - The four contract-defined compositions of ablative materials shown in Table 1 were mixed and molded in small quantities in the laboratory to gain an insight into potential methods of handling. Refer to Figures 1, 2, 3, and 4 for illustrations of the molds, and Appendix A for a description of the process used in fabricating these disk-type specimens.

Tentative conclusions reached by mixing, compression molding and cutting these four compositions in small specimens (5 inches diameter by 2 inches thick) were as follows:

(1) All four compositions require different methods of mixing, amounts of pressure during cure, and techniques for stock removal in any finishing operations that might be required.

(2) It was difficult to handle the two low-density compositions after panel fabrication because of their very fragile nature.

(3) If it were necessary to profile the total panel surface, machining operations on the two high-density compositions would be relatively time-consuming and costly because of their texture and/or hardness.

Concurrent with the compression molding of the 5-inch diameter disks, similar sized disks were molded using vacuum bag pressure. Tentative conclusions reached as a result of this effort were as follows:

(4) Achievement of uniform density throughout large panels, and from panel-to-panel, could not be readily attained through use of low pressure curing methods.

(5) Panels fabricated using vacuum or pressure bag techniques would likely require secondary finishing operations to achieve the surface finish and contour necessary for use on the outside surface of a space shuttle vehicle.

(6) Machined or sanded surfaces on the two low-density formulations are more fragile and susceptible to damage than the "as-molded" surface because the machining operation removed the very light "skin" formed on the surface during the molding operation.

(7) The "skin" (resin-rich surface) on the low density materials was thinner on the vacuum bag molded disks than it was on the compression molded disks.

TABLE 1

FORMULATION AND DENSITY REQUIREMENTS
PER NASA WORK SCOPE

FORMULAE	DENSITY (lbs. per cubic foot)	COMPOSITION ABBREVIATION
LOW DENSITY COMPOSITIONS		
Phenolic† - 15% Nylon† - 15% Microballoons† - 70%	13 - 17	15/15/70
Elastomer - 10% Microballoons - 90%	13 - 17	10/90
HIGH DENSITY COMPOSITIONS		
Phenolic - 50% Nylon - 50%	25 - 30	50/50
Elastomer† - 67% Microballoons - 33%	25 - 30	67/33

† Complete definition of all materials used is presented in Material Specifications 11138, 11191, 11192, and 11193 of Appendix B.

Based on the tentative conclusions outlined above, the decision was made to concentrate efforts on evaluating the materials under compression molding conditions. This decision was supported by these further reasons:

(1) Technical discussions with NASA indicated that all other contractors active in this effort were developing vacuum and pressure bag techniques.

(2) It is possible that in higher production quantities of panels, the costs of tools necessary for compression molds will be offset by improved panel durability, density control, and lower labor hours.

1.2 Sub-scale process development. - Prior to designing full-size panel molds for fabricating the two-foot by four-foot panels, sub-scale molds were made for evaluating two-inch thick panels in two shapes, i.e., five-inch diameter, and six-inch by six-inch square. These molds (figures 1 through 4) were used for the fabrication of panels as described therein. Figure 5 shows the flat and curved specimens made in the six-inch by six-inch mold for process evaluations, while Figure 6 shows the five-inch diameter flat specimens. Conclusions reached through the fabrication of these small disks and panels are as follows:

1.2.1 Mixing: Table 2 outlines the optimum method for mixing each of the ablative compositions. These methods evolved as a result of mixing, molding and curing the sub-scale panels during this part of the study. Phenolic microballoons were dried for a minimum of four hours at 150° prior to mixing, while the phenolic and nylon resins were kept in sealed containers as provided by their manufacturers.

1.2.2 Mold loading: Table 3 defines the results of tests made for loading techniques applicable to each of the formulations during the sub-scale molding evaluations.

1.2.3 Cure of panels: During fabrication of the sub-scale disks and panels, it was found that these parts could be removed from the mold after two hours @ 250°F. for the elastomer formulations, and three hours @ 325°F. for the nylon/phenolic formulations. These cure cycles were used during these studies.

1.2.4 Weight control: Weight control of the panels posed no apparent problems in the sub-scale evaluations. The weight of material loaded into the mold controlled the final part within the accuracy of measuring techniques used. During full-scale panel fabrication, it became apparent there was weight loss assumed due to volatile flash-off during cure. This was particularly noticeable with the 50/50 phenolic/nylon formulation. An insufficient number of full-scale panels were made to fully evaluate this problem although it is feasible, by molding additional panels, to make allowances based on experience to control weight within ±2 percent.

1.2.5 Molding pressures: Evaluations of the pressure necessary to close the mold on the various compositions were made using a hydraulic press and the five-inch diameter sub-scale mold. These measurements were made on a cold mix, while pressing each mixture into the honeycomb as would be required for molding the full-scale parts. These measurements were not intended to be precise, but rather to determine the magnitude of pressures involved in establishing the size of press necessary for full-scale panel (two-foot by four-foot) molding. The 67/33 elastomeric composition required approximately 300 psi to close the mold. All other ablative compositions required less pressure.

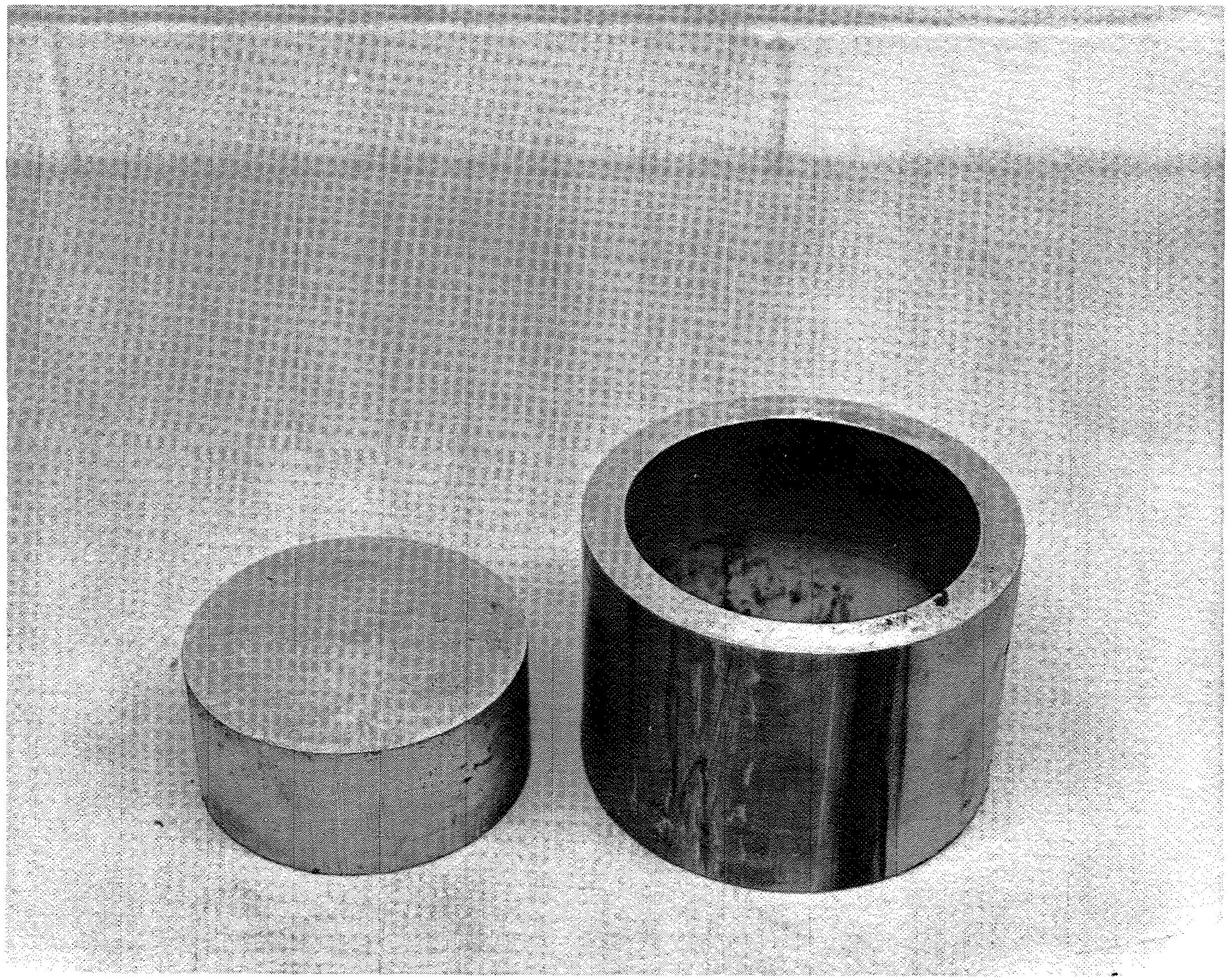

Figure 1 FIVE-INCH DIAMETER DISK COMPRESSION MOLD

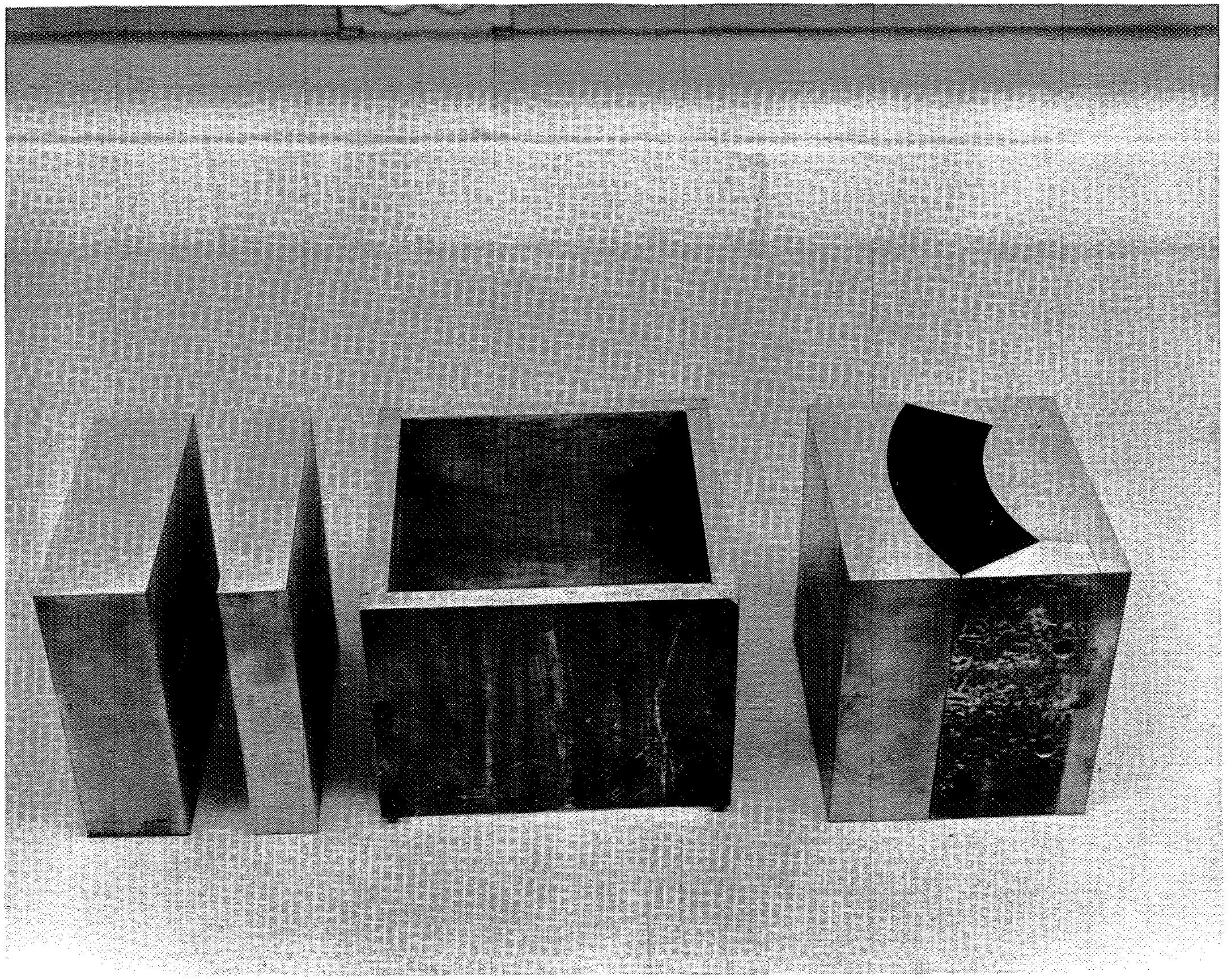

Figure 2   6-INCH SQUARE COMPRESSION MOLD
FOR FLAT OR CURVED SUB-SCALE PANELS

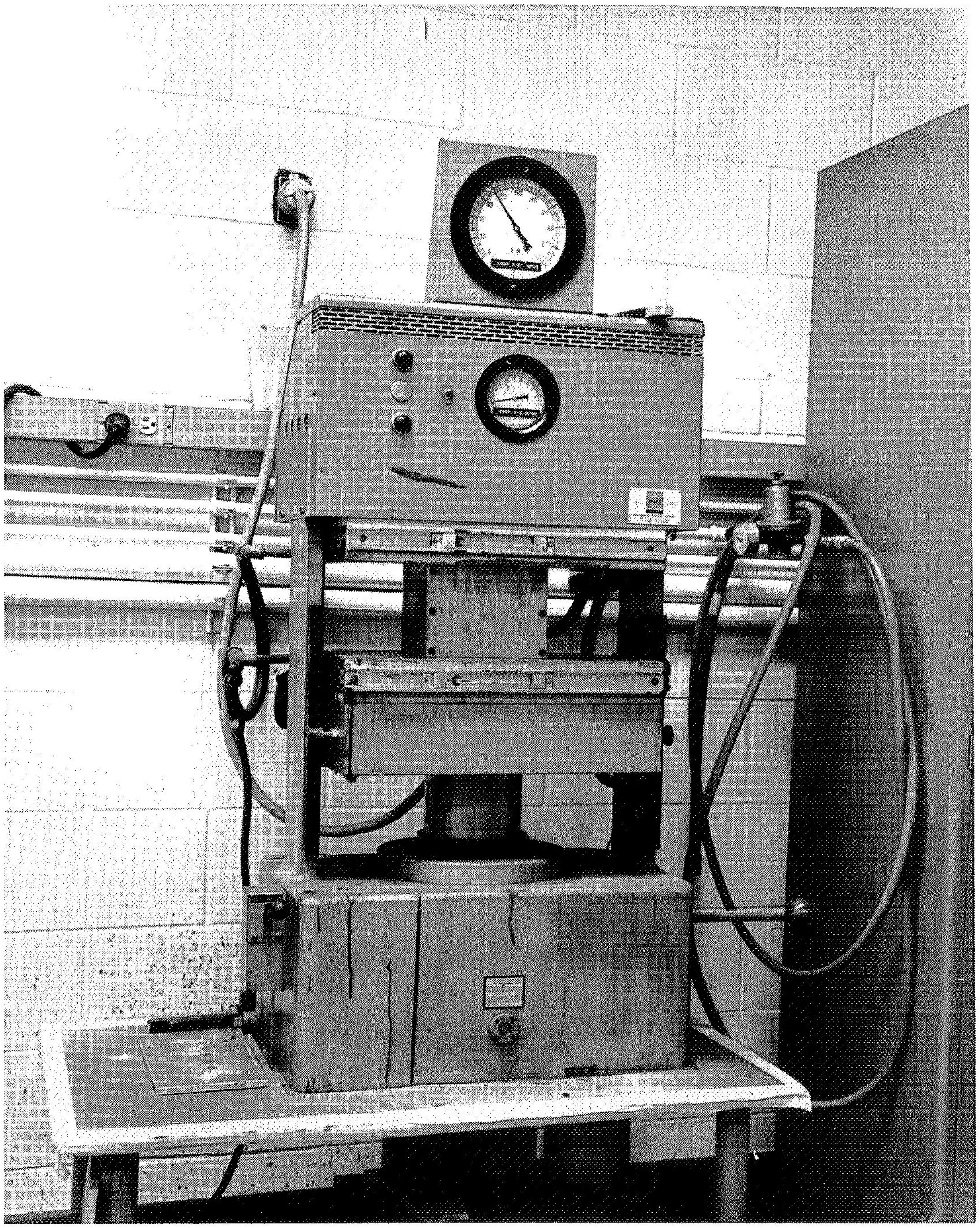

Figure 3 6-INCH SQUARE COMPRESSION MOLD
IN THE LABORATORY PRESS

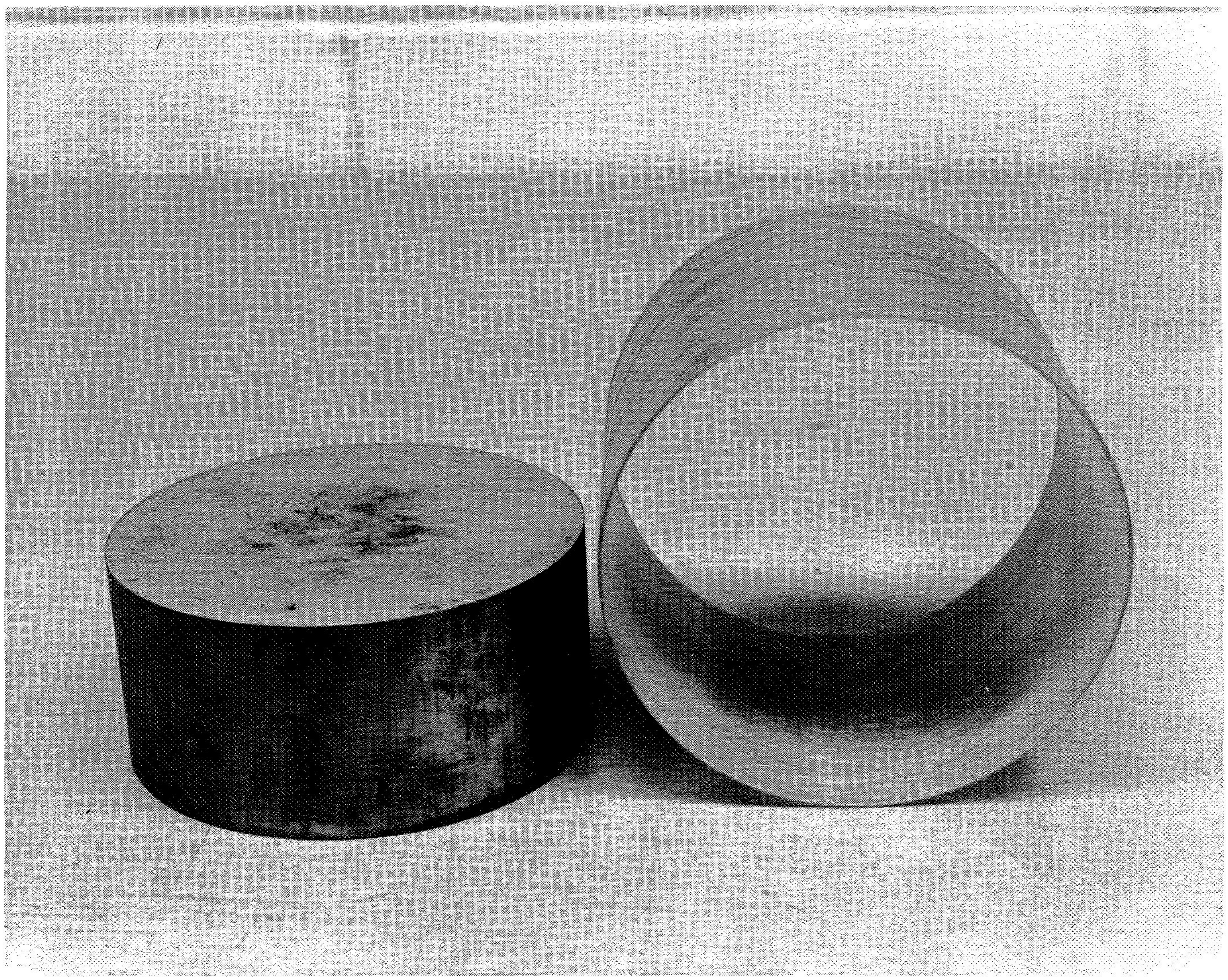

Figure 4 5-INCH DIAMETER FIBERGLASS TUBULAR MOLD WITH BASE DISK OR TOP PLATE

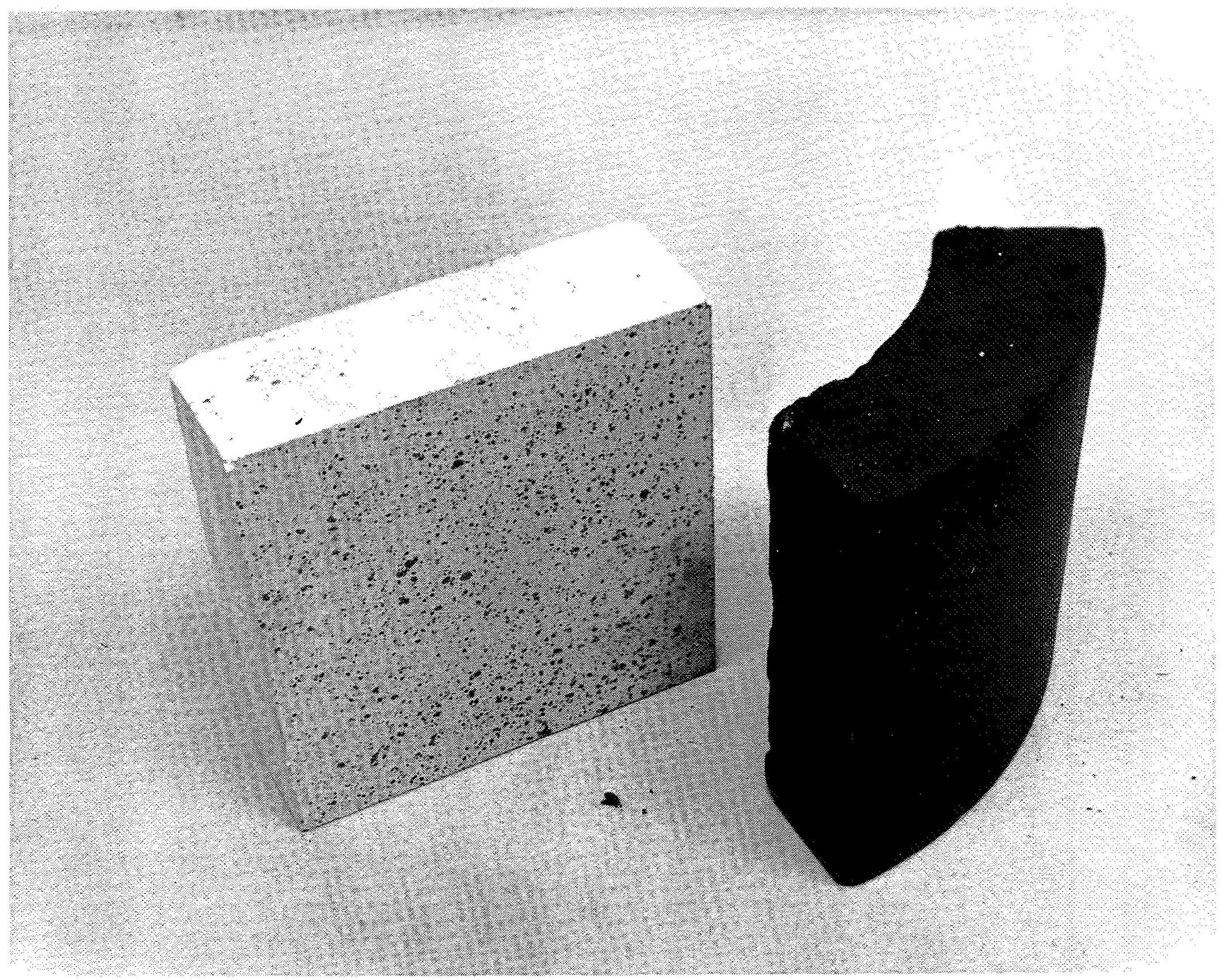

Figure 5 6-INCH SQUARE FLAT AND CURVED SUB-SCALE PANELS

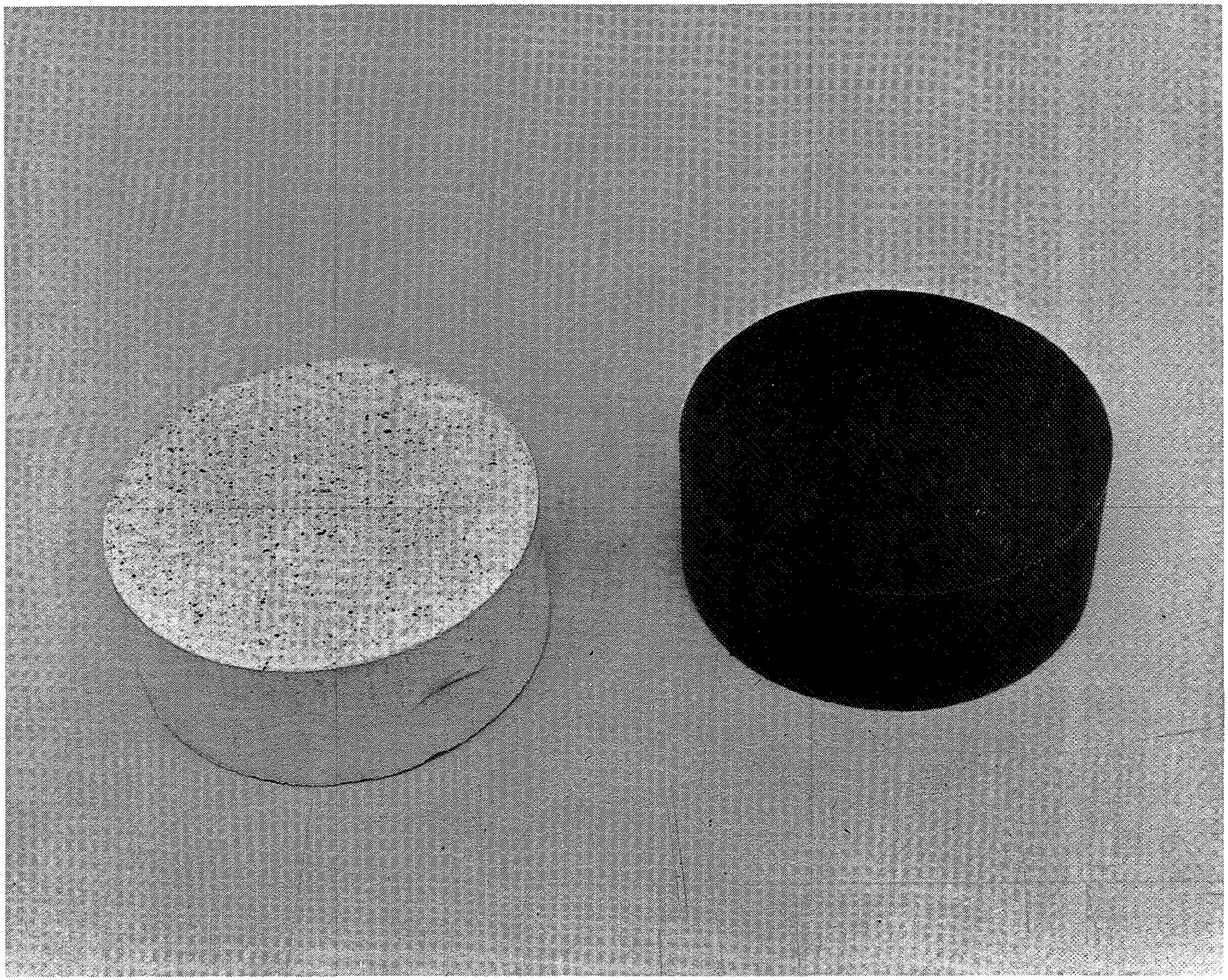

Figure 6 5-INCH DIAMETER SUB-SCALE SPECIMENS

TABLE 2
OPTIMUM MIXING METHODS

Formulation	Mixing Required
15/15/70	Easily mixed in any rotary drum mixer (Figure 7). Folding action in mixer reduces time necessary to achieve thorough mix. 1/4 full rotary drum mixer with no folding action takes 30 minutes at 20 rpm to provide thorough mix.
10/90	Requires mixing of the elastomer into a small portion (20%) of microballoon mix. Best achieved by hand mixing and forcing through 16-mesh screen at least twice. This mix can then be blended into the remainder of the microballoons in a rotary drum mixer with or without folding action. 1/4 full rotary drum mixer with no folding action takes two hours at 20 rpm to thoroughly wet the microballoons with the elastomer.
50/50	This formulation requires the same mixing as the 15/15/70 formulation.
67/33	Best mixed in rotary mixer which provides folding, shearing action. In rotary drum mixer, this formulation must be manually folded at least three times during the mix cycle. 1/4 full rotary drum mixer with no folding action takes two hours at 20 rpm to thoroughly mix this material.

During the molding of full-size panels (two-foot by four-foot), it became apparent that mold closing pressures required were related to mold loading techniques and mold clearances, as well as ablative compositions. The 300 psi above was proven to be required for both the high density compositions with the mold design defined in Figures 8, 9 and 10.

1.2.6 Dielectric cure: The initial intent in evaluating dielectric curing techniques was to determine basic feasibility of this technique relative to all of the formulations. Results of these efforts and measurements of related material parameters are as follows:

Heating of all four formulations was proven possible by use of a Model 450 LaRose Preheater operating at a frequency of 80 MHZ. This 7.5 kilowatt unit was used to heat partially-cured five-inch disks of all materials. Figure 11 shows a five-inch disk ready for heating in this unit.

These disks incorporated the honeycomb and skins. In all instances, cure temperatures within the disks were reached within 70 seconds. Internal disk temperatures were measured through use of a laboratory thermometer mounted in the disk as shown in Figure 12. The thermometer was removed during the dielectric heating process.

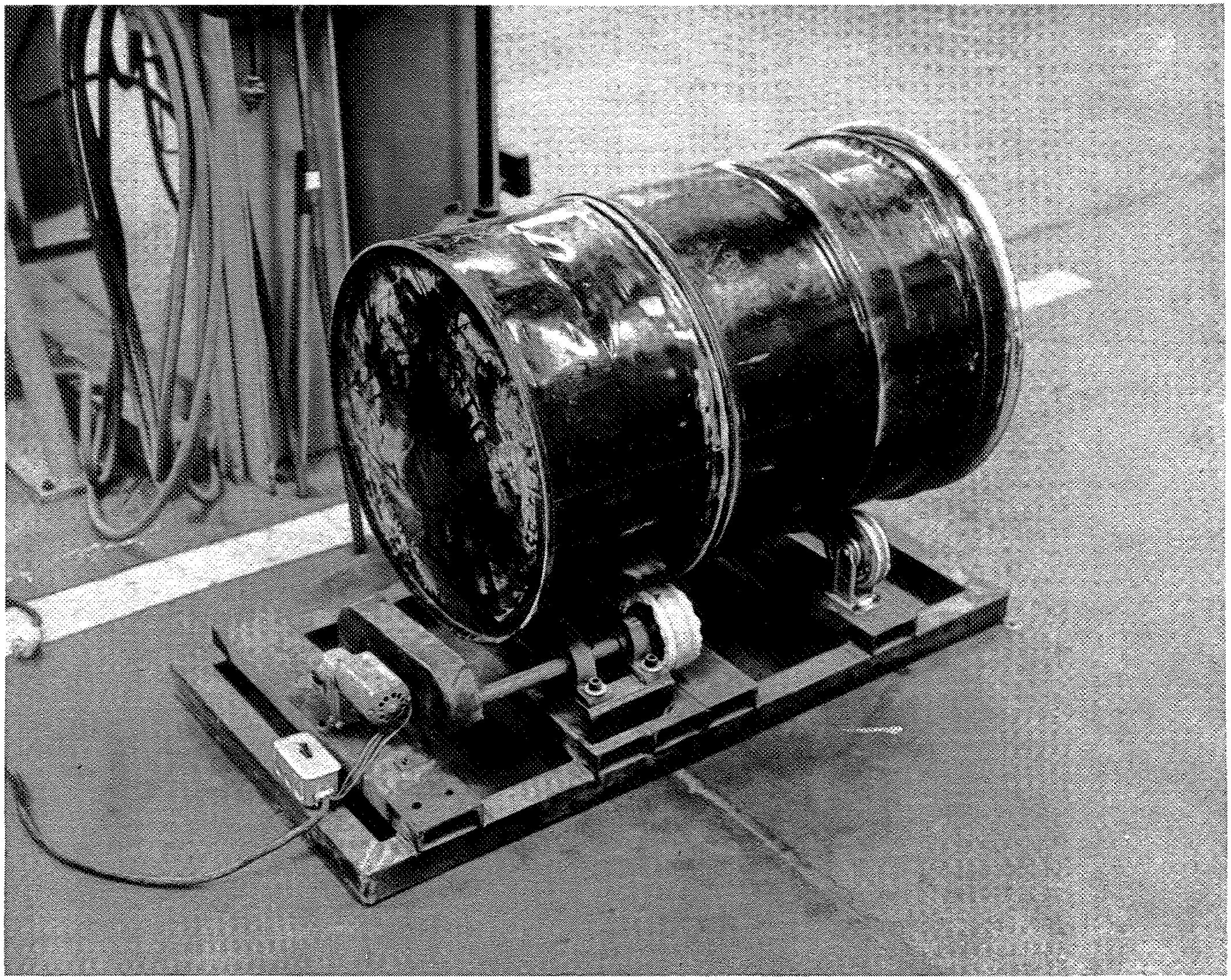

Figure 7 ROTARY DRUM MIXER USED FOR FULL SIZE PANEL MIXES

TABLE 3
MOLD LOADING TECHNIQUES

Formulation	Acceptable Techniques
15/15/70	Two methods equally acceptable: (a) Load face sheet/honeycomb into mold with honeycomb up. Fill cells with mixed ablative formulation. Level the overfill and close the mold. (b) Load the ablative mix into the mold and level the mix. Place face sheet/honeycomb into the mold with honeycomb down. Close the mold.
10/90 or 20/80	Method (a) above is acceptable; however, method (b) resulted in more consistently acceptable moldings.
50/50	Method (a) above is acceptable. Method (b) results in collapse of some of the honeycomb cell walls.
67/33	Neither (a) nor (b) resulted in uniform density of ablative material within the cells. Method (a) was favored over method (b). A more acceptable method was determined later in the program during fabrication of the full-size panels. This method requires the ablative material to be fed into the cells through a screen having 1/8-inch mesh.

Measurements of dielectric constant and loss tangent at various pertinent frequencies were made to substantiate the feasibility of this approach. The results of these tests on partially and/or fully cured samples of the four compositions incorporating the honeycomb are shown in Table 4.

Samples of the materials were sent to two manufacturers of dielectric heating equipment and presses that incorporate dielectric heating. It became apparent that further pursuit of a method and mold design for dielectric cure for this type of panel was beyond the scope of this program. Indications are that such a cure technique may be feasible with or without modifications or additions to the basic compositions; however, tests run in 27-MHZ fields on cured panel configurations (these were non-funded tests by dielectric equipment manufacturers) were too small in scope to be conclusive. Had there been funds for the pursuit of this technique as it applies to these panels, it would have been investigated further in light of the potential for reducing flow time through molds because of faster heating rates of the ablative compositions in the molds. It is further conceivable that costs of curved panel molds could be reduced by building the molds using low-loss syntactic foam and reinforced plastic materials.

While it is impossible at this writing to consider the use of dielectric heating in making cost projections, it would be desirable to further investigate these techniques because of their potential impact on cost reductions.

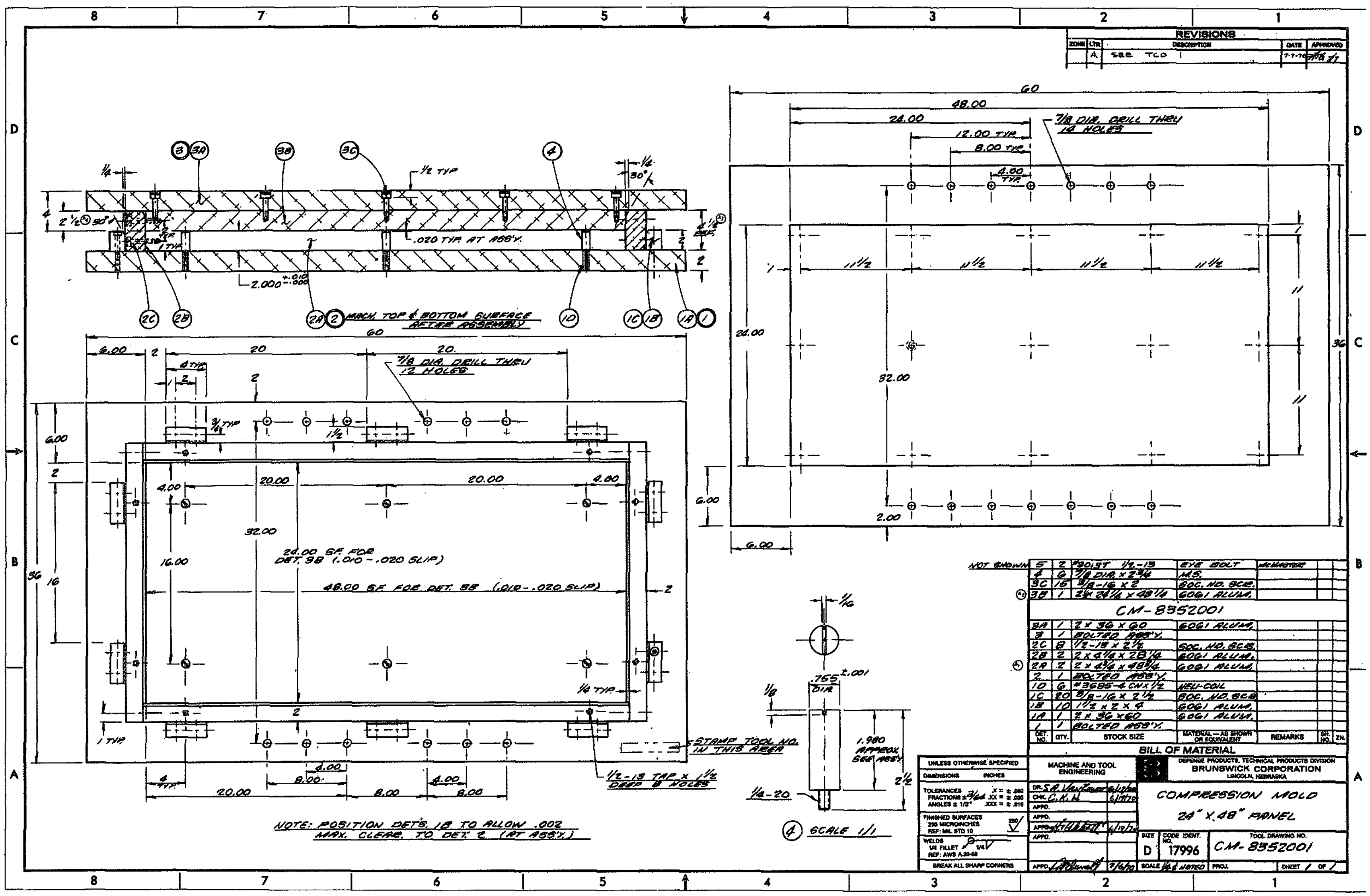

Figure 8 COMPRESSION MOLD DRAWING 24" X 48" PANEL

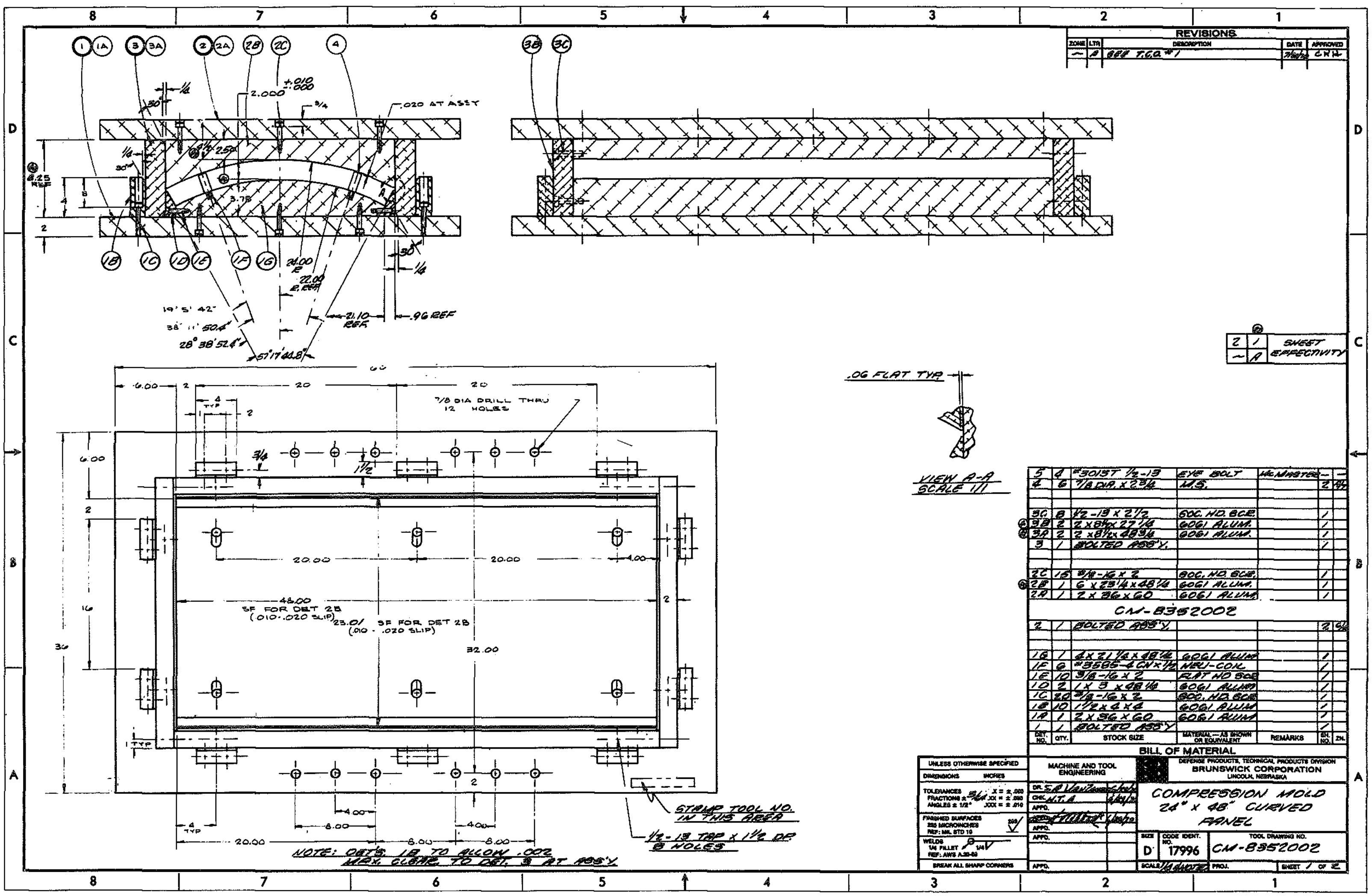

Figure 9 COMPRESSION MOLD DRAWING 24" X 48" CURVED PANEL
SHEET 1

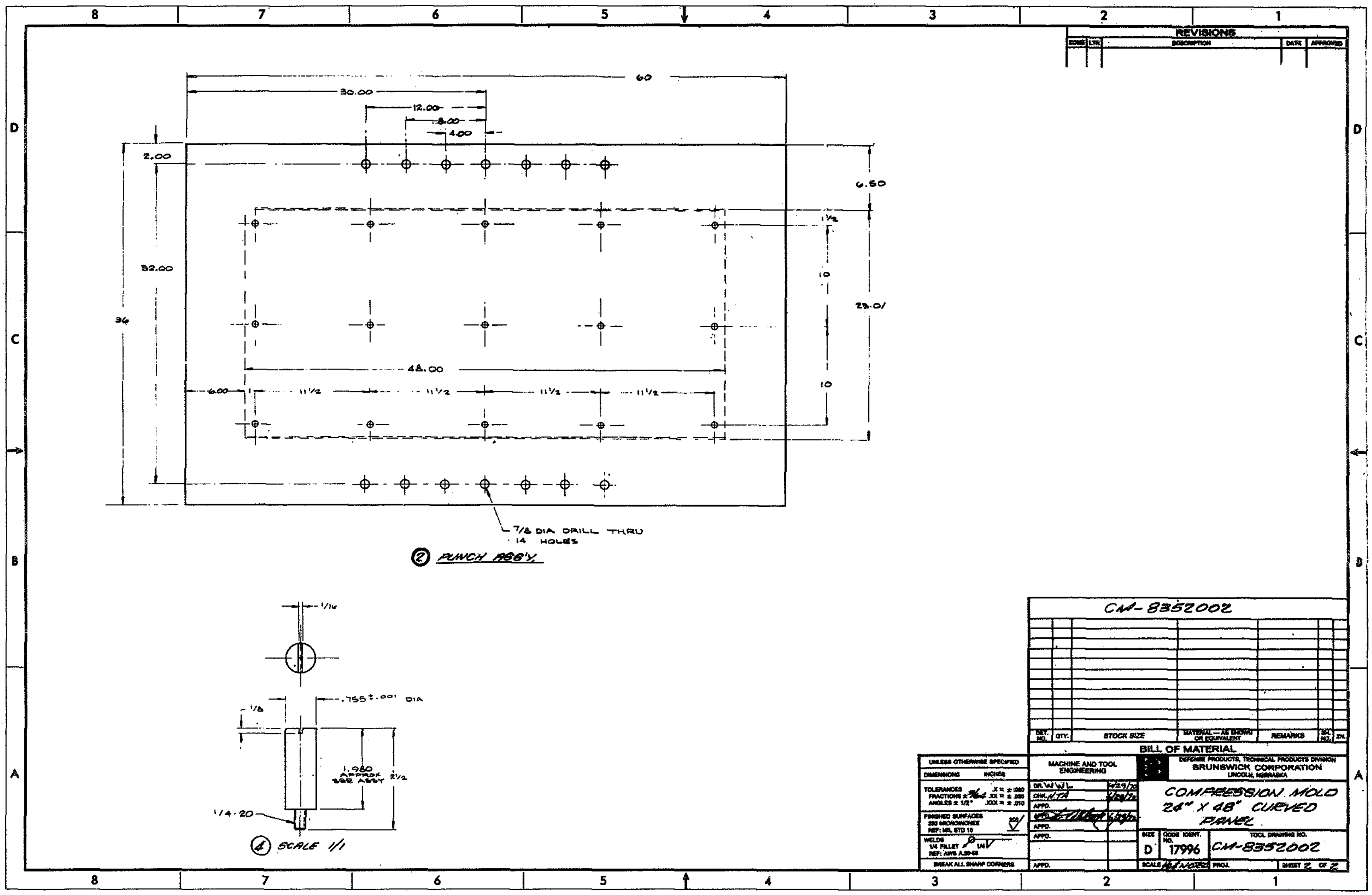

Figure 10 COMPRESSION MOLD DRAWING 24" X 48" CURVED PANEL
SHEET 2

Figure 11   5-INCH DISK SPECIMENS
MOUNTED ON MODEL 450 DIELECTRIC HEATER

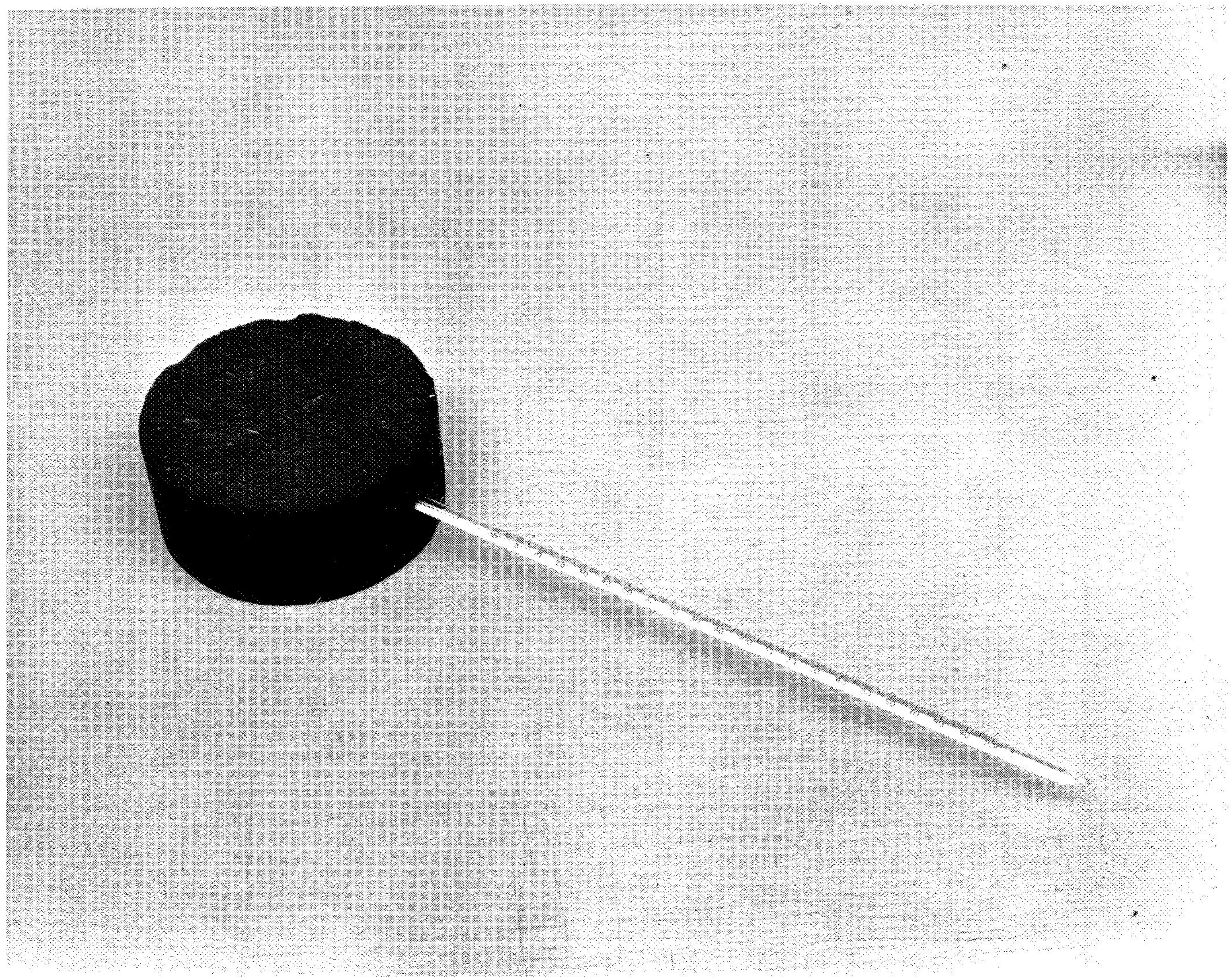

Figure 12   THERMOMETER INSERTED INTO DIELECTRICALLY HEATED SPECIMEN

TABLE 4
DIELECTRIC PROPERTIES OF ABLATIVE COMPOSITIONS

Frequency MHZ	Low Density Phenolic Nylon 15/15/70		High Density Elastomeric 33/67		Low Density Elastomeric 10/90		High Density Phenolic Nylon 50/50	
	Dielectric Constant	Loss Tangent	Dielectric Constant	Loss Tangent	Dielectric Constant	Loss Tangent	Dielectric Constant	Loss Tangent
30	1.44	.015	1.88	.022	1.41	.018	1.72	.010
50	1.42	.017	1.94	.023	1.41	.017	1.74	.011
60	1.42	.018	1.94	.023	1.41	.020	1.74	.011
80	1.45	.018	1.98	.025	1.45	.021	1.80	.015

1.2.7 Face sheet materials: Five resin systems were evaluated for potential use in the panel attachment face sheet. Based on their abilities to adequately impregnate the fiberglass face sheet reinforcement and to bond the face sheet to the honeycomb reinforcement in a single process operation, these resin systems were rated in the following order:

(1) Epon 828 Curing Agent Y
(2) Epon 828/Methane Diamine
(3) Epon 828/Tonox
(4) Epon 828/Agent CL
(5) Epon 828/EPO TUF 37-619

NOTE: Full definitions of these materials are given in Appendix B, page 55.

Face sheet/honeycomb bond tests at 300°F. did not provide maximum quantitative bond values because of premature failure of the adhesive that bonded the specimens to the support blocks, although all specimens failed at values above 24 psi. The ratings shown above also relate to the ability of each resin system to provide a fillet at the face sheet-to-honeycomb interface. All of the first three systems provided a good fillet; however, the third listed system (Epon 828/Tonox) was chosen for its low cost and ease of processing.

Face sheet/honeycomb panels were made from both 1581 style and 1582 style fiberglass cloth during the sub-scale evaluations. Wet resin layups were used during these evaluations, and the 1582 cloth/resin samples yielded superior fillets during this testing. This system was, therefore, used on initial full-scale panels. When it became necessary to install face sheets onto the panels, following or concurrent with the curing of the ablative material into the honeycomb, the wet resin system was found to provide less than optimum handling and filleting properties. Further evaluations were, therefore, performed after the flat panels were complete.

The system used for the curved panel face sheet was a 1581 style cloth with the resin "B staged" prior to incorporation into the panels. The face sheets and their bond on the curved panels are potentially superior to that achieved on the flat panels, because of the lesser tendency for resin migration from the cloth into the ablative mixture with the B staged resin. A full description of the 1582 and 1581 style cloths and the resin system components are given in the material descriptions in Appendix B.

1.2.8 Honeycomb: Prime considerations in choosing a honeycomb reinforcement for the ablative material were high temperature, stability, light weight, and ease of processing. The only economical material capable of the high temperature requirements is a glass reinforcement. The only currently available "standard" honeycomb cell size 1/2 inch or less (as required by NASA) is a 3/8-inch cell. The 3/8-inch cell fiberglass honeycomb was chosen as the lightest weight material compatible with ease of filling the cells with the ablative materials. Initial considerations were given to the use of over-expanded 3/8-inch honeycomb for curved panels because of its easier formability. Some full-size panels were fabricated using this material; however, it became evident that the tendency for the bottom of the cells to close up on the curved panels made this honeycomb difficult to fill properly and also yielded a panel more subject to cracking that resulted from shrinkage of the ablative material during cure. Overexpanded material was discarded in favor of the standard cell configuration in the lightest available (2.2 lbs./cu. ft.) fiberglass/phenolic honeycomb.

Cell collapse encountered in the molding of the sub-scale specimens using 2.2 lbs./cu. ft. honeycomb had led to the use of a stronger, higher density (4.5 lbs./cu. ft.) honeycomb in the 50/50 nylon phenolic and the 67/33 elastomer flat panels. Techniques developed during full scale flat panel molding, however, enabled the successful use of the low density (2.2 lbs./cu. ft.) in all of the curved panels. A full description of the two honeycombs used in panel fabrication is given in BMS 10106 and BMS 10107 included in Appendix B, page 57.

1.2.9 Honeycomb Primer: Selection of a primer material for the honeycomb was made through contact with the suppliers of the base resin systems used in the two different ablative material systems, i.e., elastomer and phenolic/nylon. The primer chosen for the phenolic/nylon system was a liquid phenolic resin, miscible in water, for ease and economy of application. The initial primer chosen for the elastomer system was "Sylgard Primer" as manufactured by the resin supplier. Evaluation of the two primer systems applied to the honeycomb by a dip-and-drain process led to the conclusion that phenolic resin primer gave superior bonds to the honeycomb with all four ablative material formulations on the six-inch by six-inch and five-inch diameter sub-scale molded parts. These bonds were all judged adequate based on the fact that physical destruction of the panels resulted in breaking within the ablative materials rather than at the honeycomb/ablative material interface. Complete description of the phenolic primer is given in BMS 11230 in Appendix B, page 57.

Section 2
Panel Fabrication

The purpose of this section is to outline the significant problems encountered during the fabrication of full scale panels and the solution to those problems.

The molds for the full sized panels were designed following the process development. Refer to Figures 13, 14, 15, and 16 for molds and panels. Figures 8, 9, and 10 define the molds in detail.

These molds were constructed of aluminum to maximize heating and cooling rates and also to achieve fastest possible heat input to the panels. Aluminum also provided one of the most economic means of mold fabrication. These molds were built as simply and economically as possible, consistent with the small number of panels to be made. The molds are, however, capable of producing additional panels for future evaluations if desired. No other reuseable tooling was built for the full size panels.

Processes used for full scale panel production were evolved through use of the full size molds. The exact process used for fabrication of the eight panels made for delivery to NASA is outlined in detail in the process documents contained in Appendix C. While most of the process data developed through use of the sub-scale aluminum molds was applicable to the full scale panel molding, there were a few "surprises" unveiled during full scale panel molding. These are covered in the following sub-paragraphs.

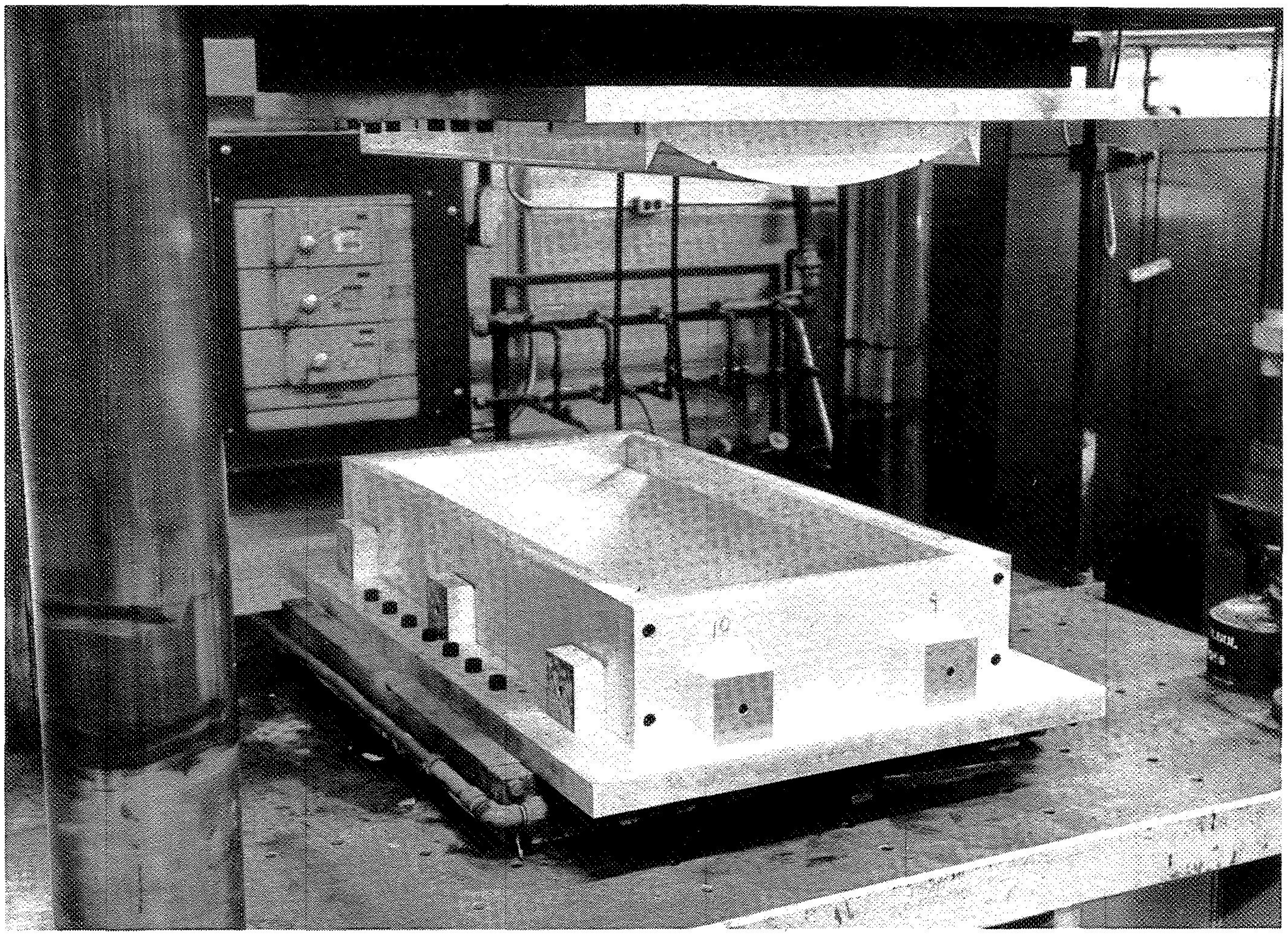

Figure 13 CLOSE-UP VIEW OF 2-FOOT BY 4-FOOT CURVED PANEL MOLD

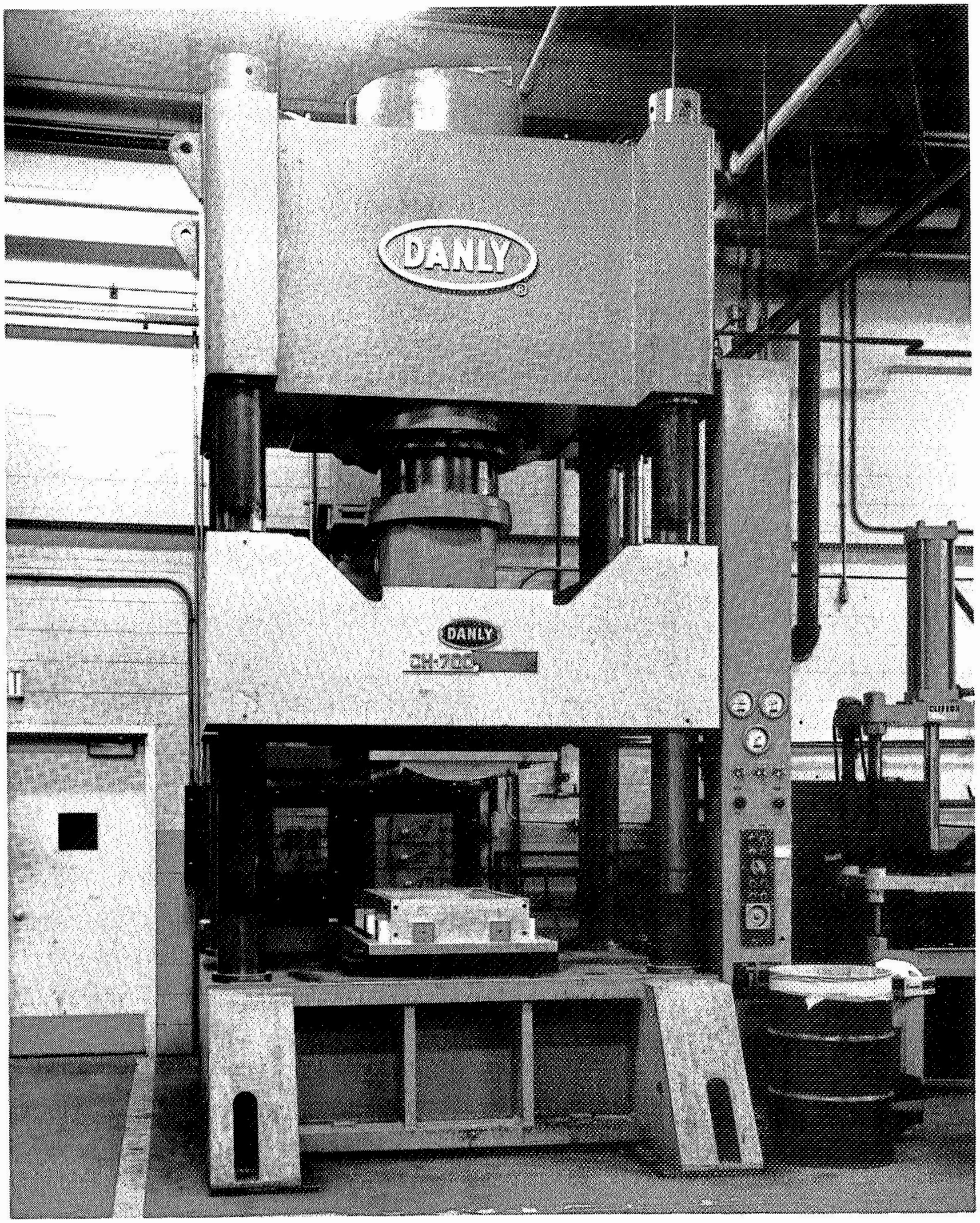

Figure 14 VIEW OF ONE OF THE COMPRESSION PRESSES IN WHICH THE 2-FOOT BY 4-FOOT PANELS WERE MOLDED

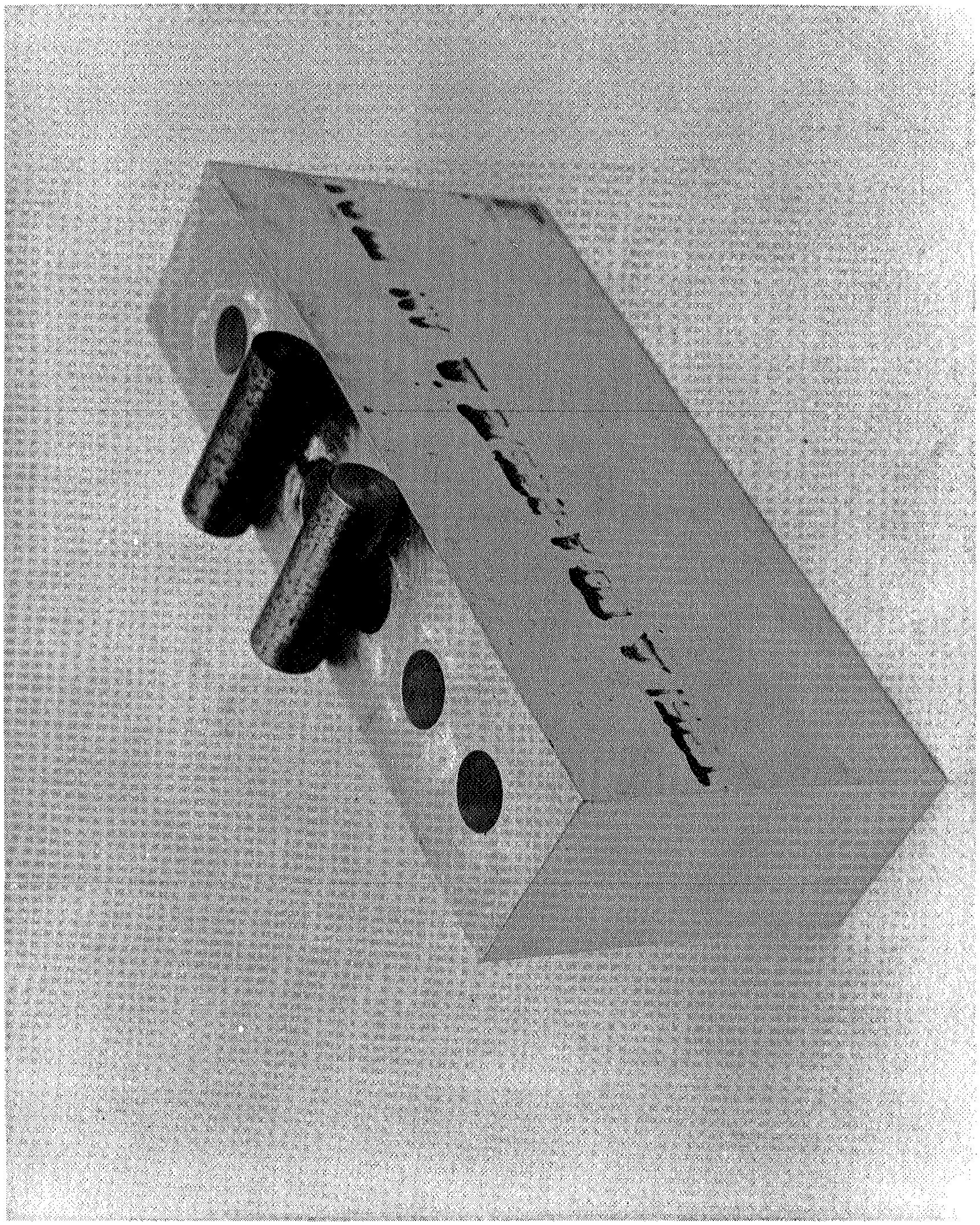

Figure 15 COMPRESSION MOLD FOR ATTACHMENT HOLE PLUGS

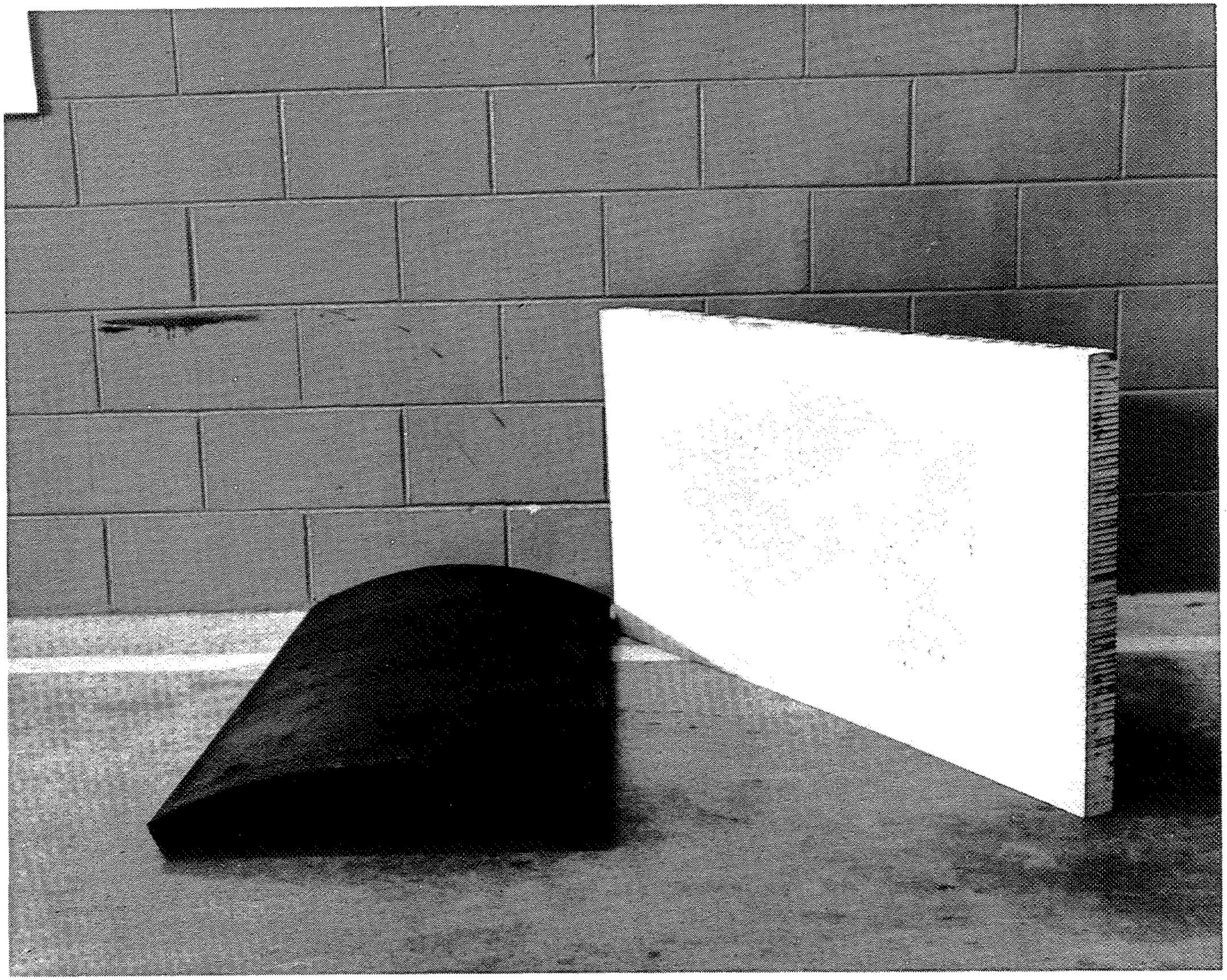

Figure 16   FULL SIZE 2-FOOT BY 4-FOOT FLAT AND CURVED PANEL

2.1 Panel warpage - Molding of the ablative materials into face sheet/honeycomb sub-assemblies resulted in panel warpage which had not been apparent in the sub-scale moldings. This warpage was attributed to the higher coefficient of expansion of the ablative materials than that of the face sheet, as well as the shrinkage which occurs in the ablative materials during their cure. This warpage of the panels was much more apparent in the high density compositions than in the low density compositions. The most severe warpage was evidenced with the 50/50 phenolic/nylon formulation.

Warpage was minimized by molding the honeycomb/ablative panel sections of the panel prior to application of the face sheet. This change in process sequence (face sheet application *after* panel molding) was approved by NASA through a change to the original contract specification which required that skins be bonded to honeycomb prior to panel molding.

2.2 Ablative material shrinkage - The excessive shrinkage which occurs during cure in the 50/50 phenolic/nylon compositions also results in inferior bond of the ablative material to the honeycomb cell walls. This was apparent even after the change in fabrication sequence noted above.

Prior to face sheet attachment, some of the 50/50 cured ablative material was not bonded to the honeycomb cell walls. Pressure molding of the face sheet onto the panel, however, resulted in flow of the face sheet resin into the unbonded cell/ablative material cracks, thus achieving a rebonding in these areas of the panel. Although further improvements in this rebond are feasible through additional experimentation with face sheet attachment techniques, the panels delivered represent what is considered an adequate bond.

2.3 Non-uniform density and cell fill. - Minor difficulties had been experienced in fabrication of sub-scale panels using the 67/33 elastomer/microballoon formulation because of its low bulk factor as mixed. These problems were much accentuated in the full-scale panel. Initially, molded full-scale panels were very uneven in density and, in fact, some of the cells were not filled with the ablative material. Techniques used unsuccessfully to pack these ablative materials into the honeycomb prior to molding included:

(1) Filling the mold with a "fluffed-up mix" prior to pressing the honeycomb into the mix.

(2) Using a "fluffed-up mix" sprinkled into the cells and over the cells of the honeycomb already in the mold.

The best technique found for filling the cells uniformly with this formulation was that of laying a 1/8-inch mesh screen immediately on top of the honeycomb and forcing the material through this screen into the cells. The additional material required to bring the panel to the desired density was then screened evenly over the honeycomb prior to closing the mold. Even with this method there is a graduation in density from highest on the top of the panel to lowest on the under side of the panel. This, however, may be desirable since it should increase the thermal efficiency of the material.

2.4 Face sheet bond. - Bonding of the face sheet onto the panels after molding was a decision made late in the program. Resin/face sheet materials were tailored early in the program to optimize techniques for face sheet/honeycomb sub-assembly prior to panel molding. These materials and their form, as used for full-scale panel molding, are not the best available for secondary face sheet bonding to already molded panels. The result is a face sheet bond which leaves something to be desired even though it meets the specified requirements for this application. A B-staged pre-impregnated epoxy/fiberglass cloth results in a more void-free face sheet on the panels. Different degrees of B-staging may be desirable for optimum bonding to the honeycomb with the high density versus the low density formulations. In any case, there is no doubt that much improvement is possible in the face sheet and its bond to the panel through further effort. Minor improvements in face sheet appearance and bond were achieved on the curved panels since these panels were molded after the flat panels. B-staging of the resin in the cloth was performed at Brunswick, i.e., not on commercial pre-impregnation equipment.

2.5 Panel edges. - The "fill-out" of the honeycomb cells around the edge of the panels which were molded to size can be improved. Dependent on the ultimate design for sealing and bonding between panels, there are several further evaluations necessary to obtain an acceptable edge on these relatively fragile panels. Patching techniques require further investigation and development. Cutback of the honeycomb around the periphery of the panel prior to molding has shown some promise of improving the appearance and smoothness of the panels around their edges. However, the lack of honeycomb support in this area leaves a wider area of the panel periphery subject to damage. Panel edges will present a problem on the low density panels during assembly although this topic will not be treated in depth in this report.

2.6 Attachment holes and plugs. - The full scale panel molds were designed to allow the attachment holes to be molded into the panels. This technique was used on initial trial panels. However, several other problems encountered in initial panel molding were complicated by this approach. Consequently, in the interests of expediency, a decision was made to mold the panels without holes. The integral molding technique is, however, still feasible and should be pursued further.

The plugs for the attachment holes were molded in the laboratory press in a simple compression mold shown in Figure 15.

Section 3
Projected Process Improvements

The following paragraphs outline further cost reduction and quality improvements which have evolved as a result of the fabrication of the eight panels delivered to NASA.

Improvements defined in paragraphs 3.1 through 3.4 have been built into cost projections in Section 4, while subsequent paragraphs are subject to further consideration and evaluation and are considered speculative at this time.

3.1 "B-staged" resin in face sheets.- The use of well-controlled B-staged resin systems in the cloth will provide a consistent quality of relatively void-free face sheets on the panels. Some of the delivered panels have very good quality face sheets. Improved process controls and use of resin systems more specifically designed for pressure laminating can result in consistent face sheet quality.

3.2 Pre-packed panel edges. - Techniques used for filling the honeycomb with ablative material around the edges of the panels were not optimized during production of the small quantity of delivered panels. Some of the last-made curved panels showed improvement over the flat panels due to improvements in mold loading techniques. Further improvements in edge packing and development of mechanically controlled screening techniques should be considered for production of larger numbers of panels, particularly for use with the elastomeric compositions.

3.3 Molded-in attachment holes. - As noted previously in Section 2, the holes in delivered panels are drilled holes. It is practical to consider molding the holes into the panels, provided the hole pattern is reasonably consistent for any panel shape considered.

3.4 Post-cure of panels.- Panels made for delivery to date have been cured for the full 16 hours (dictated by contract requirements) in the aluminum molds. This is not necessary and would not allow maximum possible panel output from the compression molds. Sub-scale parts were not post-cured, yet were cooled and removed in two to three hours from initiation of the cure. Full-scale panels can be processed in the same manner and subjected to an oven post-cure to achieve the full 16-hour requirement, if necessary.

It is possible that an adequate cure can be achieved in a short period (two to three hours) without post cure, particularly when the cure takes place in a steam heated aluminum mold which can be heated or cooled in a very short time. Cure temperatures for both the elatomeric and the nylon/phenolic compositions can be increased by at least 50°F. to achieve faster cures while the panel is in the compression mold. Feasibility of this approach has been verified on sub-scale panels. Further evaluations would be required on full-scale panels to establish optimized cure cycles.

3.5 Localized face sheets. - All delivered panels have face sheets over the complete rear or attachment surface of the panel. This complicates molding, particularly of the high density panels. As stated previously, these panels require a separate operation and curing cycle for face sheet bonding and curing because of their high shrinkage. Resin flow resulting from any face sheet bond necessitates time-consuming cleanup of the panels. Face sheet over the entire rear surface makes the panel less flexible. Elimination of most of this face sheet would make the elastomeric panels much more readily conformable to the outside surface of the space vehicle.

All of the considerations indicate the use of very localized, well-bonded, structurally superior face sheets. This could be readily accomplished by use of either B-staged or pre-cured fiberglass/resin face sheets bonded during initial ablative material cure using sheet or foaming sheet adhesives to accomplish the improved bond strength.

3.6 Resin skinning of panels. - The low density ablative compositions are structurally weak and very susceptible to damage from handling. This characteristic problem could probably be overcome through use of a relatively flexible resin skin built onto the surface and edges of the panels during initial cure. This resin skin could be kept relatively economical through use of a flexible polyester, epoxy, or elastomeric resin system applied to the mold surface prior to loading and curing the panel.

3.7 Composition variation. - Use of compression molding techniques for production of ablative panels provides avenues for considering variations in the ablative material compositions. This is particularly relevant to the 67/33 elastomeric composition. The large ratio of the high cost elastomer could be substantially reduced in this formulation without making the composition difficult to mold to a comparable level of density. This would substantially reduce the cost of panels made from this composition. Ablative performance versus formulation composition would be evaluated on a cost effectiveness basis using the capabilities of compression molding for sample fabrication.

3.8 Dielectric cure. - This is perhaps the most speculative of the improvements presented in this report. However, its impact on mold cost and the number of molds required to produce large quantities of panels indicates that it should not be overlooked. The impact would be most significant on panels with multiple curvatures where a long cure on the panel requires excessive mold tie-up time and post cure could require a support mold to preclude panel distortion.

The use of dielectric cure should be evaluated on a minimum number of useful ablative compositions since dielectric heating properties of the materials require thorough evaluation prior to commitment to a mold design. It would, therefore, be more practical to investigate dielectric curing techniques after candidate ablative compositions have been reduced in number, and when other potential advantages of compression molded panels, such as reproduceability of quality and density control, are a proven requirement.

Section 4
Cost Projections

The techniques used in the fabrication of the eight delivered panels required by this contract represent the use of relatively expensive equipment and molds. The decision to use such techniques and to prove their feasibility within the time span and projected cost of this contract dictated a relatively conservative approach to the actual processes used. Now that feasibility is evident, there are several minor modifications to the actual processes used to date which will substantially reduce the ultimate costs of production panels. As noted in Section 3, the following such modifications have been incorporated into the cost projections outlined in this section.

(1) "B-staged" resin in the face sheet
(2) Pre-packed panel edges
(3) Molded-in attachment holes
(4) Post-cure of panels

Cost projections are presented herein for each of the four compositions in each of the following panel configurations. All panels are two inches in thickness.

(a) two-foot by four-foot flat panel

(b) two-foot by four-foot curved panel (single curvature on a two-foot radius on the outside surface of the panel). Curvature is in the two-foot width direction of the panel. See Figure 16.

(c) three-foot by five-foot flat panel

(d) four-foot by six-foot flat panel

Cost projections are also given for a two-foot by four-foot panel with curvature in two directions. Radius of curvature is not constant in either direction. These projections are given only for the two high density ablative compositions.

Cost projections shown in Tables 5, 6 and 7 are based on the use of equipment, tooling, material costs, and labor estimates presented in sub-sections 4.1 through 4.5 of this report. These cost projections are given for lot sizes of one (1), ten (10), and one hundred (100) of each of the panel configuration/composition combinations previously outlined. All panel costs shown in the tables include amortizations of special tooling and equipment but include no profit.

Panel cost projections include the types of equipment and tooling listed in Tables 8, 9 and 10 in quantities necessary to fabricate panels for up to 10 flights per year with the following panel mix per ship set:

	High Density Panels	Low Density Panels
2' x 4' Flat Panels	100	100
2' x 4' Curved Panels	125	125
2' x 4' Double Curvature Panels	250	
3' x 5' Flat Panels	40	40
4' x 6' Flat Panels	25	25

Estimates in Tables 8, 9 and 10 for equipment costs are shown only as a guide to define the type required. Mold costs are based on vendor quotations. Mold and post-cure fixture quantities required are based on flow times summarized in Tables 23 and 24 and shown in detail in Tables 28 through 45 in Appendix C. Post-cure fixtures are used to minimize mold flow times. Post-cure of flat panels would be achieved through use of caul plates between panels.

4.2 Materials. - Materials cost estimates were initially made for one (1), ten (10), and one hundred (100) flights. However, the quantity of materials used in one flight (25,000 lbs. of ablative material for 8,000 square feet of ablative panel) is large enough that further increases have a very insignificant

TABLE 5

COST SUMMARY, IN LOTS OF 1 PANEL

ABLATIVE COMPOSITION	COST (DOLLARS PER SQUARE FOOT)				
	2' X 4' FLAT	2' X 4' CURVED	2' X 4' DOUBLE CURVATURE	3' X 5' FLAT	4' X 6' FLAT
HIGH DENSITY NYLON PHENOLIC	128.00	138.00	146.00	116.00	115.00
HIGH DENSITY ELASTOMERIC	142.00	153.00	162.00	130.00	128.00
LOW DENSITY NYLON PHENOLIC	117.00	128.00	-	104.00	102.00
LOW DENSITY ELASTOMERIC	120.00	131.00	-	109.00	107.00

TABLE 6

COST SUMMARY, IN LOTS OF 10 PANELS

ABLATIVE COMPOSITION	COST (DOLLARS PER SQUARE FOOT)				
	2' X 4' FLAT	2' X 4' CURVED	2' X 4' DOUBLE CURVATURE	3' X 5' FLAT	4' X 6' FLAT
HIGH DENSITY NYLON PHENOLIC	51.00	54.00	59.00	46.00	46.00
HIGH DENSITY ELASTOMERIC	64.00	68.00	74.00	59.00	59.00
LOW DENSITY NYLON PHENOLIC	41.00	45.00	-	36.00	36.00
LOW DENSITY ELASTOMERIC	44.00	48.00	-	40.00	40.00

TABLE 7

COST SUMMARY, IN LOTS OF 100 PANELS

ABLATIVE COMPOSITION	COST (DOLLARS PER SQUARE FOOT)				
	2' X 4' FLAT	2' X 4' CURVED	2' X 4' DOUBLE CURVATURE	3' X 5' FLAT	4' X 6' FLAT
HIGH DENSITY NYLON PHENOLIC	44.00	47.00	53.00	41.00	41.00
HIGH DENSITY ELASTOMERIC	57.00	61.00	66.00	54.00	54.00
LOW DENSITY NYLON PHENOLIC	36.00	39.00	-	33.00	32.00
LOW DENSITY ELASTOMERIC	40.00	43.00	-	35.00	35.00

TABLE 8

SPECIAL PURPOSE EQUIPMENT REQUIRED

Description	Approximate Cost (New)
Honeycomb Slicing Equipment	$ 40,000.00
200-Ton Press (for 2' x 4' panel size)	25,000.00
Post Cure Oven 10' x 20' x 8'	20,000.00

TABLE 9

TOOLS (GENERAL)

Description	Approximate Selling Price
Dip Tank for Honeycomb Prime	$ 1,500.00
Panel Mold	Various, see Table 10
Plug Mold 24-Cavity	$ 3,000.00
Panel Post-Cure Fixtures	Various, see Table 10
Honeycomb Forming Jig for Curved Panels	$ 3,500.00
Ablative Mixer (sized for 2' x 4' panels)	$ 1,000.00
Impregnation Fixture for Face Sheet	$ 6,000.00

effect on material costs per panel. The material costs reported in the following tables, therefore, do not differentiate between 1 and 100 flight quantities.

Raw material costs are based on current quotations from suppliers as defined in Table 26 in Appendix B and assume that each space shuttle flight will consume 8,000 square feet of ablative panels equal to 25,000 lbs. of ablative material.

Waste allowances used for materials are defined in Table 27 in Appendix B. Miscellaneous process materials and unit costs of same are outlined in Table 25 in Appendix B.

Material costs for larger flat panel sizes (three-foot by five-foot and four-foot by six-foot) will not be tabulated in detail as they are simply a multiple of the materials used for fabrication of the two-foot by four-foot flat panels outlined in Table 11 through 18. Table 19, therefore, summarizes the total costs of materials for the three-foot by five-foot and four-foot by six-foot panel sizes. Material costs used for double curvature panels are the same as those for single curvature panels.

TABLE 10

ESTIMATED COSTS FOR VARIOUS PANEL MOLDS AND FIXTURES

Mold or Fixture Description	Estimated Selling Price
2-foot by 4-foot Flat Panel Mold	$ 4,800.00
2-foot by 4-foot Single Curvature Mold	6,600.00
2-foot by 4-foot Double Curvature Mold	12,400.00 †
3-foot by 5-foot Flat Panel Mold	6,600.00
4-foot by 6-foot Flat Panel Mold	8,000.00
2-foot by 4-foot Single Curvature Post-Cure Fixture	700.00
2-foot by 4-foot Double Curvature Post Cure Fixture	1,000.00 †
2-foot by 4-foot Single Curvature Honeycomb Form Tool	700.00
2-foot by 4-foot Double Curvature Honeycomb Form Tool	1,000.00 †

†Costs for double curvature tools assume the supply of a master model by the prime contractor.

4.3 Labor. - Labor estimates incorporated into the cost projections for production of the panels are based on the experience gained in fabricating the eight (8) delivered panels. They assume that there would have to be several flights planned to justify the equipment and tooling costs involved, and that some panels would be made in small quantities, i.e., one to ten pieces per flight, while others would be required in larger lots per flight, i.e., ten to 100. They further assume that panel order quantities would encompass several planned shuttle flights. Man-hours estimated herein assume that approximately 800 panels would be required per flight and that any order quantity would provide for five flights or approximately 4,000 panels. Man-hours for larger or smaller order quantities would be expected to follow a 90 percent learning curve for this type of panel fabrication. The procedures used are all hand-type lot or batch processing techniques. If there were many flights planned, i.e., in excess of 10 per year, there would probably be justification for greater automation of mixing, mold loading, and handling. Such methods

TABLE 11

MATERIAL COSTS FOR
HIGH DENSITY NYLON PHENOLIC
2-FOOT BY 4-FOOT FLAT PANEL

Material Desription	Material Specification Number	Quantity Required Per Panel	Cost Per Panel
Fiberglass Cloth	10003	.94 sq. yds.	$ .71
Epoxy Resin	11104	.64 lbs.	.30
Hardener	11018	.18 lbs.	.10
Primer	11230	.52 lbs.	.14
Honeycomb	10106	1.53 cu. ft.	48.10
Nylon Resin	11191	15.25 lbs.	46.51
Phenolic Resin	11192	15.25 lbs.	4.50
Miscellaneous Process Materials	Appendix B, Table 25		3.00
Total Cost Per Panel			$103.00

TABLE 12

MATERIAL COSTS FOR
HIGH DENSITY ELASTOMERIC
2-FOOT BY 4-FOOT FLAT PANEL

Material Desription	Material Specification Number	Quantity Required Per Panel	Cost Per Panel
Fiberglass Cloth	10003	.94 sq. yds.	$ .71
Epoxy Resin	11104	.64 lbs.	.30
Hardener	11018	.18 lbs.	.10
Primer	11230	.52 lbs.	.14
Honeycomb	10106	1.53 cu. ft.	48.10
Microballoons	11138	11.69 lbs.	11.46
Elastomeric Resin	11193	23.73 lbs.	91.36
Miscellaneous Process Materials	Appendix B, Table 25		3.00
Total Cost Per Panel			$155.00

TABLE 13

MATERIAL COSTS FOR
LOW DENSITY PHENOLIC NYLON
2-FOOT BY 4-FOOT FLAT PANEL

Material Description	Material Specification Number	Quantity Required Per Panel	Cost Per Panel
Fiberglass Cloth	10003	.94 sq. yds.	$ .71
Epoxy Resin	11104	.64 lbs.	.30
Hardener	11018	.18 lbs.	.10
Primer	11230	.52 lbs.	.14
Honeycomb	10106	1.53 cu. ft.	48.10
Nylon Resin	11191	2.43 lbs.	7.41
Phenolic Resin	11192	2.43 lbs.	.72
Microballoons	11138	11.33 lbs.	10.76
Miscellaneous Process Materials	Appendix B, Table 25		3.00
Total Cost Per Panel			$71.00

TABLE 14

MATERIAL COSTS FOR
LOW DENSITY ELASTOMERIC
2-FOOT BY 4-FOOT FLAT PANEL

Material Desription	Material Specification Number	Quantity Required Per Panel	Cost Per Panel
Fiberglass Cloth	10003	.94 sq. yds.	$ .71
Epoxy Resin	11104	.64 lbs.	.30
Hardener	11018	.18 lbs.	.10
Primer	11230	.52 lbs.	.14
Honeycomb	10106	1.53 cu. ft.	48.10
Microballoons	11138	13.19 lbs.	12.53
Elastomeric Resin	11193	3.30 lbs.	12.71
Miscellaneous Process Materials	Appendix B, Table 25		3.00
Total Cost Per Panel			$78.00

TABLE 15

MATERIAL COSTS FOR
HIGH DENSITY NYLON PHENOLIC
2-FOOT BY 4-FOOT CURVED PANEL

Material Desription	Material Specification Number	Quantity Required Per Panel	Cost Per Panel
Fiberglass Cloth	10003	.86 sq. yds.	$ .65
Epoxy Resin	11104	.58 lbs.	.27
Hardener	11018	.16 lbs.	.09
Primer	11230	.52 lbs.	.13
Honeycomb	10106	1.53 cu. ft.	48.10
Nylon Resin	11191	14.61 lbs.	44.56
Phenolic Resin	11192	14.61 lbs.	4.31
Miscellaneous Process Materials	Appendix B, Table 25		2.75
Total Cost Per Panel			$101.00

TABLE 16

MATERIAL COSTS FOR
HIGH DENSITY ELASTOMERIC
2-FOOT BY 4-FOOT CURVED PANEL

Material Desription	Material Specification Number	Quantity Required Per Panel	Cost Per Panel
Fiberglass Cloth	10003	.86 sq. yds.	$ .65
Epoxy Resin	11104	.58 lbs.	.27
Hardener	11018	.16 lbs.	.09
Primer	11230	.52 lbs.	.13
Honeycomb	10106	1.53 cu. ft.	48.10
Microballoons	11138	11.20 lbs.	10.98
Elastomeric Resin	11193	22.73 lbs.	87.52
Miscellaneous Process Materials	Appendix B, Table 25		2.75
Total Cost Per Panel			$150.00

TABLE 17

MATERIAL COSTS FOR
LOW DENSITY NYLON PHENOLIC
2-FOOT BY 4-FOOT CURVED PANEL

Material Description	Material Specification Number	Quantity Required Per Panel	Cost Per Panel
Fiberglass Cloth	10003	.86 sq. yds.	$ .65
Epoxy Resin	11104	.58 lbs.	.27
Hardener	11018	.16 lbs.	.09
Primer	11230	.52 lbs.	.13
Honeycomb	10106	1.53 cu. ft.	48.10
Nylon Resin	11191	2.33	7.09
Phenolic Resin	11192	2.33	.69
Microballoons	11138	10.85	10.30
Miscellaneous Process Materials	Appendix B, Table 25		2.75
Total Cost per Panel			$70.00

TABLE 18

MATERIAL COSTS FOR
LOW DENSITY ELASTOMERIC
2-FOOT BY 4-FOOT CURVED PANEL

Material Desription	Material Specification Number	Quantity Required Per Panel	Cost Per Panel
Fiberglass Cloth	10003	.86 sq. yds.	$ .65
Epoxy Resin	11104	.58 lbs.	.27
Hardener	11018	.16 lbs.	.09
Primer	11230	.52 lbs.	.13
Honeycomb	10106	1.53 cu. ft.	48.10
Microballoons	11138	12.64 lbs.	12.00
Elastomeric Resin	11193	3.16 lbs.	12.18
Miscellaneous Process Materials	Appendix B, Table 25		2.75
Total Cost Per Panel			$76.00

TABLE 19

TOTAL MATERIAL COSTS FOR THREE-FOOT BY FIVE-FOOT AND FOUR-FOOT BY SIX-FOOT FLAT PANELS

Type of Panel	Total Material Costs	
	3-ft. x 5-ft.	4-ft. x 6-ft.
High Density Nylon/Phenolic	$193	$309
High Density Elastomeric	291	465
Low Density Nylon/Phenolic	133	213
Low Density Elastomeric	146	234

have not been considered when compiling these estimates. It is difficult to conceive valid reasons for using compression molding techniques for a single panel. Costs presented here for a single panel are acknowledged to be conservative. If compression molding techniques must be made applicable to single panels, all of the circumstances surrounding such a requirement should be fully defined and a thorough analysis applied to this requirement.

Tables 20, 21, and 22 summarize the man-hours required per panel for each of the panel shapes, sizes, and compositions estimated.

Tables 23 and 24 summarize the flow times for each of the molds for the various panel configurations and compositions. There is no relevancy to single panel flow times so no summary is presented for single panel lots. Detailed breakdowns of the man-hour and flow-time estimates are given in Appendix C in Tables 28 through 45. Flow-time estimates for the molds assume the use of two men during the mold loading operation for the 2-foot by 4-foot panels, and three men for larger panel sizes.

TABLE 20

SUMMARY OF MAN-HOURS PER PANEL
IN LOTS OF 1 PANEL

ABLATIVE COMPOSITION	Man-Hours				
	2' X 4' FLAT	2' X 4' CURVED	2' X 4' DOUBLE CURVATURE	3' X 5' FLAT	4' X 6' FLAT
HIGH DENSITY NYLON/PHENOLIC	25.3	28.9	30.2	37.9	58.0
HIGH DENSITY ELASTOMERIC	27.8	32.3	34.0	42.6	65.9
LOW DENSITY NYLON/PHENOLIC	22.1	26.7		32.5	48.4
LOW DENSITY ELASTOMERIC	23.3	27.4		34.7	52.0

TABLE 21

SUMMARY OF MAN-HOURS PER PANEL
IN LOTS OF 10 PANELS

ABLATIVE COMPOSITION	MAN-HOURS				
	2' X 4' FLAT	2' X 4' CURVED	2' X 4' DOUBLE CURVATURE	3' X 5' FLAT	4' X 6' FLAT
HIGH DENSITY NYLON/PHENOLIC	12.1	13.4	14.2	18.9	30.7
HIGH DENSITY ELASTOMERIC	14.2	16.0	17.2	22.8	37.2
LOW DENSITY NYLON/PHENOLIC	9.7	11.3		15.0	23.9
LOW DENSITY ELASTOMERIC	10.6	12.4		17.0	26.6

TABLE 22

SUMMARY OF MAN-HOURS PER PANEL
IN LOTS OF 100 PANELS

ABLATIVE COMPOSITION	MAN-HOURS				
	2' X 4' FLAT	2' X 4' CURVED	2' X 4' DOUBLE CURVATURE	3' X 5' FLAT	4' X 6' FLAT
HIGH DENSITY NYLON/PHENOLIC	9.5	10.8	11.7	15.5	24.9
HIGH DENSITY ELASTOMERIC	11.6	13.3	14.5	19.2	31.1
LOW DENSITY NYLON/PHENOLIC	7.7	9.0		12.4	19.1
LOW DENSITY ELASTOMERIC	8.5	10.1		13.9	21.6

TABLE 23

SUMMARY OF PANEL FLOW TIME THROUGH
THE COMPRESSION MOLD IN LOTS OF 10 PANELS

ABLATIVE COMPOSITION	FLOW TIMES				
	2' X 4' FLAT	2' X 4' CURVED	2' X 4' DOUBLE CURVATURE	3' X 5' FLAT	4' X 6' FLAT
HIGH DENSITY NYLON/PHENOLIC	9.1	9.1	9.3	10.6	11.7
HIGH DENSITY ELASTOMERIC	8.9	9.5	10.5	9.6	12.4
LOW DENSITY NYLON/PHENOLIC	6.1	6.0		6.6	7.9
LOW DENSITY ELASTOMERIC	5.3	5.5		6.0	7.3

TABLE 24

SUMMARY OF PANEL FLOW TIME THROUGH THE COMPRESSION MOLD IN LOTS OF 100 PANELS

ABLATIVE COMPOSITION	FLOW TIMES				
	2' X 4' FLAT	2' X 4' CURVED	2' X 4' DOUBLE CURVATURE	3' X 5' FLAT	4' X 6' FLAT
HIGH DENSITY NYLON/PHENOLIC	8.2	8.1	8.4	9.4	10.3
HIGH DENSITY ELASTOMERIC	8.0	8.6	9.4	8.5	10.9
LOW DENSITY NYLON/PHENOLIC	5.4	5.3		5.8	6.8
LOW DENSITY ELASTOMERIC	4.6	4.6		5.1	6.2

CONCLUSIONS

Funding limitations dictated a conservative approach to the relatively unproven use of compression molding techniques to these ablative material compositions in large size panels. Further evaluations should be considered to expand the knowledge of the process variables which could affect ablative panel performance. Conclusions reached are, therefore, limited to those outlined below which relate to the basic objectives of the work scope.

(1) Successful fabrication techniques have been developed and implemented for ablative panels made from each of the four ablative material compositions defined by the NASA contract.

(2) Cost estimates for panel fabrication have been defined (See Section 4 of the report).

(3) Compression molded ablative panels are low in cost when compared with techniques used to date for application of ablative materials to vehicles such as the Apollo capsules. Costs of panel fabrication (not including tools) vary from 31 dollars per square foot to 69 dollars per square foot in lots of 10 to 100 panels.

(4) A number of facets of the compression molding process are worthy of further development to achieve lower cost and/or improved quality for the ablative panels. These are discussed in Section 3 of this report.

(5) Compression molding techniques for ablative panels will probably be most competitive with other fabrication techniques on higher quantities of flat or single curvature panels because of the relatively high tooling costs. Dielectric cure in non-metallic molds may offer a way to improve their competitive position for lower quantities or for double curvature panels. Development costs of such techniques would be substantial and would require thorough cost evaluations relative to the potential savings before such development was undertaken.

(6) Panels delivered varied in quality because of the learning which was still in progress when the last panel was made. The curved panels, which were produced last, are superior in quality to the flat panels.

APPENDIX A
SUB-SCALE MOLDING PROCESS

Figures 1, 2, and 3 show the sub-scale molds and press used for molding sub-scale disks and blocks and the 50-ton laboratory press used with these molds. The press has electrically heated platens which were brought to the cure temperature prior to loading the molds into the press. Cure temperature for the nylon/phenolic compositions was 300°F., and 250°F. for the elastomeric compositions. These molds were loaded cold, outside the press, with the ablative composition with or without honeycomb and face sheets, then carried to the press for compression and cure. The molds were all made of aluminum which reached cure temperatures approximately five minutes after loaded into the hot press. Upon removal from the press, the molds were allowed to cool in ambient room temperature to approximately 150°F., at which time the parts were removed from the mold.

A five-inch inside diameter fiberglass tube with a two-inch thick aluminum base disk was used for vacuum molding the four compositions (see figure 4). This was accomplished by setting the tubular portion of the mold over its top plate on a piece of bleeder cloth. The tubular part of the mold was then raised up on blocks to create a cavity in excess of two inches deep in the tube portion of the mold. After this cavity was loaded with ablative mixture, the blocks were removed from under the tube (which is light and snug on the top plate with the ablative mix in it) and a bleeder cloth and vacuum bag sealed and evacuated over the complete mold. This assembly was then put into an oven and cured. It was then cooled in room temperature environment to 150° F. and the part removed from the mold.

This fiberglass tube and 2-inch thick aluminum disk was also used for initial compression molding trial parts, but was subsequently replaced by the aluminum for its better temperature conductive properties and heat-up rate in the press.

APPENDIX B
MATERIALS

<u>Descriptions of Resins, Hardeners, and Fabrics Evaluated for use in Panel Skins</u>

EPON 828	Standard Epoxy Resin (made by Shell Chemical Company)
Curing Agent Y	Standard Curing Agent for Epoxy Resin (made by Shell Chemical Company)
Menthane Diamine	Standard Curing Agent for Epoxy Resin (made by Aldrich Chemical Company)
Tonox.	Standard Curing Agent for Epoxy Resin (made by Naugatuck Chemical Company)
Curing Agent CL.	Standard Curing Agent for Epoxy Resin (made by Shell Chemical Company)
EPOTUF 39-619	Standard Curing Agent for Epoxy Resin (made by Reichhold Chemical Company)
1581 Fabric.	Glass Cloth with 8-Harness Satin Weave weighing 9.00 ounces per square yard (made by J. P. Stephens and Company, Inc.)
1582 Fabric.	Glass Cloth with 8-Harness Satin Weave weighing 13.45 ounces per square yard (made by J. P. Stephens and Company, Inc.)

TABLE 25

MISCELLANEOUS PROCESS MATERIALS

Description of Material	Approximate Unit Cost
Silicone Release Fabric	$1.16 per square yard
PVA Vacuum Bag Film	.80 per square yard
Mold Release.	1.60 per 8-oz. can
Mylar Film.	.38 per square yard
Vacuum Bag Sealant.	.07 per foot

TABLE 26

MATERIAL DESCRIPTIONS

Material Specification Number	Description	Manufacturer and Trade Name (if any)	Unit Cost
10003	1581 Style Fiberglass Cloth	United Merchants Industrial Fabrics	$0.755/sq. yd.
10106	3/8 CELL Fiberglass/ Phenolic Honeycomb 2.2 lbs. per cubic foot density	Hexcel Corporation (3/8 HRP GF-11-2.2)	31.44/cu. ft.
11004	Epoxy Resin	Shell Chemical Co. (EPON 828)	0.475/lb.
11018	Curing Agent for Epoxy Resins	Uniroyal, Inc. (Tonox)	0.58/lb.
11138	Phenolic Microballoons (or microspheres)	Union Carbide Corp. BJO-0930	0.95/lb.
11191	Powdered Nylon Resin	Polymer Corp. (Polypenco 66D)	3.05/lb.
11192	Powdered Phenolic Resin	Union Carbide (BRP-5549)	0.29/lb.
11193	Elastomeric Resin System (2 component)	Dow Corning (Sylgard 182)	3.85/lb.
11230	Liquid Phenolic Resin (Primer)	Union Carbide (BRL-1100)	0.27/lb.
10107	3/8 CELL Fiberglass/ Phenolic Honeycomb 4.5 lbs. per cubic foot density	Hexcel Corporation (3/8 HRP GF-13-4.5)	

TABLE 27

RAW MATERIAL WASTE ALLOWANCES

Material Specification Number	Material Description	% Waste †	Reason for Waste
10003	Fiberglass Cloth (for skins)	5	Cutting from standard width
11004	Epoxy Resin (for skins)	10	Clean up of impregnating equipment
11018	Hardener (for skins)	10	Clean up of impregnating equipment
11230	Primer (for honeycomb)	5	Clean up of dip trays, etc.
10106	Honeycomb	10	Cutting from standard sizes
11138	Phenolic Microballoons	†† 8 or 3	Mixing and handling waste
11192	Phenolic Resin	3	Mixing and handling waste
11191	Nylon Resin	3	Mixing and handling waste
11193	Elastomer	8	Mixing and handling waste

† The above waste allowances are considered normal at medium production volumes and may be high for maximum volume production. They were used for all calculations for consistency.

†† Dependent on whether microballoons are mixed with the phenolic/nylon or the elastomer.

APPENDIX C
ESTIMATED MAN-HOURS AND DETAILED PROCESSING

Set-up times in the Labor Estimate Tables include:

Installation and removal of the mold from the press
Set-up of honeycomb cutting equipment
Set-up and cleaning of mixer
Set-up of honeycomb forming jig (curved panels only)

Flow times are shown only for operations which tie up a mold or post-cure fixture for the curved panels. For a more detailed description of each operation, the processes in this appendix refer to the same operation numbers as used in these tables.

TABLE 28

ESTIMATED HOURS FOR FABRICATION OF A
HIGH DENSITY NYLON PHENOLIC
2-FOOT BY 4-FOOT FLAT PANEL

OPERATION NUMBER	OPERATION DESCRIPTION	MAN-HOURS			FLOW TIME		
		1 PANEL	10 PANELS	100 PANELS	1 PANEL	10 PANELS	100 PANELS
1.3	Set-Up Time	8.25	.83	.08	5.50	.55	.05
1.3A	Cut Honeycomb	1.65	1.05	.75			
1.4	Prime Honeycomb	1.20	.60	.45			
1.5	Mix Ablative (.5 hr.)	1.20	.75	.60			
1.6	Weigh, Calculate	.08	.08	.08			
1.7	Measure Mix	.30	.23	.23			
1.8	Load Mold	3.00	1.80	1.65	1.50	.90	.82
1.9	Cure Panel (3 hours)	.75	.60	.60	3.75	3.60	3.60
1.10	Cool and Open Mold	.30	.30	.30	.30	.30	.30
1.11	Remove Panel, Deflash & Reassemble Mold	2.40	1.80	1.65	1.20	.60	.55
1.12	Prepare Skin	1.20	.75	.45	.60	.37	.22
1.13	Apply Skin & Clean-up Panel	2.40	1.65	1.35	3.20	2.82	2.67
1.15	Weigh Panel & Inspect	.30	.30	.30			
1.16-1.18	Mold Plugs	.75	.60	.30			
	Post Cure Panel(13 hrs)	1.50	.75	.75			
	Totals	25.28	12.09	9.54	17.55	9.14	8.21

TABLE 29

ESTIMATED HOURS FOR FABRICATION OF A
HIGH DENSITY ELASTOMERIC
2-FOOT BY 4-FOOT FLAT PANEL

OPERATION NUMBER	OPERATION DESCRIPTION	MAN-HOURS			FLOW TIME		
		1 PANEL	10 PANELS	100 PANELS	1 PANEL	10 PANELS	100 PANELS
2.3	Set-Up Time	8.25	.83	.08	5.50	.55	.05
2.3A	Cut Honeycomb	1.65	1.05	.75			
2.4	Prime Honeycomb	1.20	.60	.45			
2.5	Mix Ablative (2 hrs)	1.95	1.20	1.05			
2.6	Weigh, Calculate	.08	.08	.08			
2.7	Measure Mix	.30	.23	.23			
2.8	Load Mold	5.25	3.75	3.45	2.62	1.87	1.72
2.9	Cure Panel (2 hrs)	.75	.60	.60	2.75	2.60	2.60
2.10	Cool & Open Mold	.30	.30	.30	.30	.30	.30
2.11	Remove Panel, Deflash & Reassemble Mold	2.55	1.95	1.73	.85	.65	.57
2.12	Prepare Skin	1.20	.75	.45	.60	.37	.22
2.13	Apply Skin & Clean-up Panel	1.80	1.20	1.05	2.90	2.60	2.57
2.15	Weigh Panel & Inspect	.30	.30	.30			
2.16-2.18	Mold Plugs	.75	.60	.30			
	Post Cure Panel(14 hrs)	1.50	.75	.75			
	Totals	27.83	14.19	11.57	15.52	8.94	8.03

TABLE 30

ESTIMATED HOURS FOR FABRICATION OF A
LOW DENSITY NYLON PHENOLIC
2-FOOT BY 4-FOOT FLAT PANEL

OPERATION NUMBER	OPERATION DESCRIPTION	MAN-HOURS			FLOW TIME		
		1 PANEL	10 PANELS	100 PANELS	1 PANEL	10 PANELS	100 PANELS
3.3	Set-up Time	8.25	.83	.08	5.50	.55	.05
3.3A	Cut Honeycomb	1.65	1.05	.75			
3.4	Prime Honeycomb	1.20	.60	.45			
3.5	Mix Ablative (.5 hr.)	1.20	.75	.60			
3.6	Weigh, Calculate	.08	.08	.08			
3.7	Measure Mix	.30	.23	.23			
3.8	Load Mold	3.00	1.80	1.65	1.50	.90	.82
3.9	Prepare Skin & Apply	1.20	.75	.60	.60	.37	.30
3.10	Cure Panel (3 hrs)	.75	.60	.60	3.75	3.60	3.60
3.11	Cool & Open Mold	.30	.30	.30	.30	.30	.30
3.12	Remove Panel, Deflash & Reassembly Mold	1.65	1.05	.98	.55	.35	.32
3.14	Weigh Panel & Inspect	.30	.30	.30			
3.15-3.18	Mold Plugs	.75	.60	.30			
	Post Cure Panel (13 hr)	1.50	.75	.75			
	Totals	22.13	9.69	7.67	12.20	6.07	5.39

TABLE 31

ESTIMATED HOURS FOR FABRICATION OF A
LOW DENSITY ELASTOMERIC
2-FOOT BY 4-FOOT FLAT PANEL

OPERATION NUMBER	OPERATION DESCRIPTION	MAN-HOURS			FLOW TIME		
		1 PANEL	10 PANELS	100 PANELS	1 PANEL	10 PANELS	100 PANELS
4.3	Set-up Time	8.25	.83	.08	5.50	.55	.05
4.3A	Cut Honeycomb	1.65	1.05	.75			
4.4	Prime Honeycomb	1.20	.60	.45			
4.5	Mix Ablative (2 hrs)	1.95	1.20	1.05			
4.6	Weigh, Calculate	.08	.08	.08			
4.7	Measure Mix	.30	.23	.23			
4.8	Load Mold	3.45	2.25	2.03	1.72	1.12	1.01
4.9	Prepare Skin & Apply	1.20	.75	.60	.60	.37	.30
4.10	Cure Panel (2 hrs)	.75	.60	.60	2.75	2.60	2.60
4.11	Cool and Open Mold	.30	.30	.30	.30	.30	.30
4.12	Remove Panel, Deflash & Reassemble Mold	1.65	1.05	.98	.55	.35	.32
4.14	Weigh Panel & Inspect	.30	.30	.30			
4.15-4.18	Mold Plugs	.75	.60	.30			
	Post Cure Panel(14 hrs)	1.50	.75	.75			
	Totals	23.33	10.59	8.50	11.42	5.29	4.58

TABLE 32

ESTIMATED HOURS FOR FABRICATION OF A
HIGH DENSITY NYLON PHENOLIC
2-FOOT BY 4-FOOT CURVED PANEL

OPERATION NUMBER	OPERATION DESCRIPTION	MAN-HOURS			FLOW TIME		
		1 PANEL	10 PANELS	100 PANELS	1 PANEL	10 PANELS	100 PANELS
11.3	Cut & Form Honeycomb	2.85	1.80	1.50			
11.4	Set-up Time	9.75	.98	.09	6.50	.65	.06
11.5	Prime Honeycomb	1.20	.60	.45			
11.6	Mix Ablative (.5 hr.)	1.20	.75	.60			
11.7	Weigh, Calculate	.08	.08	.08			
11.8	Measure Mix	.30	.23	.23			
11.9	Load Mold	3.45	2.10	1.95	1.77	1.05	.97
11.10	Cure Panel (3 hrs)	.75	.60	.60	3.75	3.60	3.60
11.11	Cool & Open Mold & Remove Panel & Reassemble Mold	2.40	1.80	1.65	.80	.60	.55
11.12	Prepare Skin	1.20	.75	.45	.40	.25	.15
11.13	Apply Skin	1.05	.90	.75	3.05	2.90	2.75
11.14	Clean-up Panel	1.35	.75	.60			
11.16	Weigh Panel & Inspect	.30	.30	.30			
11.17-11.20	Mold Plugs	.75	.60	.30			
	Post Cure Panel(13 hrs)	2.25	1.20	1.20	15.25	14.20	14.20
	Totals	28.88	13.44	10.75	16.27	9.05	8.08

TABLE 33

ESTIMATED HOURS FOR FABRICATION OF A
HIGH DENSITY ELASTOMERIC
2-FOOT BY 4-FOOT CURVED PANEL

OPERATION NUMBER	OPERATION DESCRIPTION	MAN-HOURS			FLOW TIME		
		1 PANEL	10 PANELS	100 PANELS	1 PANEL	10 PANELS	100 PANELS
12.3	Cut & Form Honeycomb	2.85	1.80	1.50			
12.4	Set-up Time	9.75	.98	.09	6.50	.65	.06
12.5	Prime Honeycomb	1.20	.60	.45			
12.6	Mix Ablative (2 hr.)	1.95	1.20	1.05			
12.7	Weigh, Calculate	.08	.08	.08			
12.8	Measure Mix	.30	.23	.23			
12.9	Load Mold	5.70	4.05	3.75	2.85	2.02	1.87
12.10	Cure Panel (2 hrs)	.75	.60	.60	2.75	2.60	2.60
12.11	Cool & Open Mold & Reassemble	1.20	.75	.75	.40	.25	.25
12.12	Remove Panel & Repack	1.80	1.20	1.05	1.80	1.20	1.05
12.13	Prepare Skin	1.20	.75	.45	.40	.25	.22
12.14	Apply Skin & Clean-up	2.25	1.65	1.50	2.75	2.55	2.50
12.16	Weigh Panel & Inspect	.30	.30	.30			
12.17-12.19	Mold Plugs	.75	.60	.30			
	Post Cure Panel(14 hrs)	2.25	1.20	1.20	16.25	15.20	15.20
	Totals	32.33	15.99	13.30	17.45	9.52	8.55

TABLE 34

ESTIMATED HOURS FOR FABRICATION OF A
LOW DENSITY NYLON PHENOLIC
2-FOOT BY 4-FOOT CURVED PANEL

OPERATION NUMBER	OPERATION DESCRIPTION	MAN-HOURS			FLOW TIME		
		1 PANEL	10 PANELS	100 PANELS	1 PANEL	10 PANELS	100 PANELS
13.3	Cut & Form Honeycomb	2.85	1.80	1.50			
13.4	Set-up Time	9.75	.98	.09	6.50	.65	.06
13.5	Prime Honeycomb	1.20	.60	.45			
13.6	Mix Ablative (.5 hr)	1.20	.75	.60			
13.7	Weigh, Calculate	.08	.08	.08			
13.8	Measure Mix	.30	.23	.23			
13.9	Prepare Skin	1.20	.75	.45	.40	.25	.22
13.10	Load Mold	3.45	2.10	1.95	1.77	1.05	.97
13.11	Cure Panel (3 hrs)	.75	.60	.60	3.75	3.60	3.60
13.12	Cool, Open & Reassemble Mold	1.20	.75	.68	.40	.25	.23
13.13	Remove Panel & Clean-up	1.35	.60	.53	.45	.20	.17
13.15	Weigh Panel & Inspect	.30	.30	.30			
13.16-13.19	Mold Plugs	.75	.60	.30			
	Post Cure Panel(13 hrs)	2.25	1.20	1.20	15.25	14.20	14.20
	Totals	26.63	11.34	8.96	13.27	6.00	5.25

TABLE 35

ESTIMATED HOURS FOR FABRICATION OF A
LOW DENSITY ELASTOMERIC
2-FOOT BY 4-FOOT CURVED PANEL

OPERATION NUMBER	OPERATION DESCRIPTION	MAN-HOURS			FLOW TIME		
		1 PANEL	10 PANELS	100 PANELS	1 PANEL	10 PANELS	100 PANELS
14.3	Cut & Form Honeycomb	2.85	1.80	1.50			
14.4	Set-up Time	9.75	.98	.09	6.50	.65	.06
14.5	Prime Honeycomb	1.20	.60	.45			
14.6	Mix Ablative (2 hr)	1.95	1.20	1.05			
14.7	Weigh, Calculate	.08	.08	.08			
14.8	Measure Mix	.30	.23	.23			
14.9	Prepare Skin & Apply	1.20	.75	.60	.40	.25	.20
14.10	Load Mold	4.05	2.70	2.40	2.02	1.35	1.20
14.11	Cure Panel (2 hrs)	.75	.60	.60	2.75	2.60	2.60
14.12	Cool and Open Mold	.30	.30	.30	.30	.30	.30
14.13	Remove Panel, Deflash & Reassemble Mold	1.65	1.05	.98	.55	.35	.27
14.15	Weigh Panel & Inspect	.30	.30	.30			
14.16-14.19	Mold Plugs	.75	.60	.30			
	Post Cure Panel(14 hrs)	2.25	1.20	1.20	16.25	15.20	15.20
	Totals	27.38	12.39	10.08	12.52	5.50	4.63

TABLE 36

ESTIMATED HOURS FOR FABRICATION OF A
HIGH DENSITY NYLON/PHENOLIC
2-FOOT BY 4-FOOT DOUBLE CURVATURE PANEL

OPERATION NUMBER	OPERATION DESCRIPTION	MAN-HOURS			FLOW TIME		
		1 PANEL	10 PANELS	100 PANELS	1 PANEL	10 PANELS	100 PANELS
41.3	Cut, Form Honeycomb	2.85	1.80	1.50			
41.4	Set-up Time	9.75	.98	.09	6.50	.65	.06
41.5	Prime Honeycomb	1.35	.75	.60			
41.6	Mix Ablative (.5 hr)	1.20	.75	.75			
41.7	Weigh, Calculate	.08	.08	.08			
41.8	Measure Mix	.30	.23	.23			
41.9	Load Mold	4.05	2.40	2.25	2.02	1.20	1.12
41.10	Cure Panel (3 hrs)	.75	.60	.60	3.75	3.60	3.60
41.11	Cool & Open Mold & Remove Panel & Reassemble Mold	2.40	1.80	1.65	.80	.60	.55
41.12	Prepare Skin	1.20	.75	.45	.40	.25	.15
41.13	Apply Skin	1.35	1.05	.90	3.35	3.05	2.90
41.14	Clean-up Panel	1.35	.75	.60			
41.16	Weigh Panel & Inspect	.30	.30	.30			
41.17-41.20	Mold Plugs	.75	.60	.30			
	Post Cure Panel(13 hrs)	2.55	1.35	1.35	15.55	14.35	14.35
	Totals	30.23	14.19	11.65	16.82	9.35	8.38

TABLE 37

ESTIMATED HOURS FOR FABRICATION OF A
HIGH DENSITY ELASTOMERIC
2-FOOT BY 4-FOOT DOUBLE CURVATURE PANEL

OPERATION NUMBER	OPERATION DESCRIPTION	MAN-HOURS			FLOW TIME		
		1 PANEL	10 PANELS	100 PANELS	1 PANEL	10 PANELS	100 PANELS
42.3	Cut and Form Honeycomb	2.85	1.80	1.50			
42.4	Set-up Time	9.75	.98	.09	6.50	.65	.06
42.5	Prime Honeycomb	1.35	.75	.60			
42.6	Mix Ablative (2 hr)	1.95	1.20	1.05			
42.7	Weigh, Calculate	.08	.08	.08			
42.8	Measure Mix	.30	.23	.23			
42.9	Load Mold	6.45	4.80	4.50	3.22	2.40	2.25
42.10	Cure Panel (2 hrs)	.75	.60	.60	2.75	2.60	2.60
42.11	Cool & Open Mold & Reassemble	1.20	.75	.75	.80	.50	.50
42.12	Remove Panel & Repack	1.80	1.20	1.05	1.80	1.20	1.05
42.13	Prepare Skin	1.20	.75	.45	.40	.25	.15
42.14	Apply Skin & Clean-up	2.70	1.80	1.65	3.35	2.90	2.82
42.16	Weigh Panel & Inspect	.30	.30	.30			
42.17-42.19	Mold Plugs	.75	.60	.30			
	Post Cure Panel(14 hrs)	2.55	1.35	1.35	16.55	15.35	15.35
	Totals	33.98	17.19	14.50	18.82	10.50	9.43

TABLE 38

ESTIMATED HOURS FOR FABRICATION OF A
HIGH DENSITY NYLON PHENOLIC
3-FOOT BY 5-FOOT FLAT PANEL

OPERATION NUMBER	OPERATION DESCRIPTION	MAN-HOURS			FLOW TIME		
		1 PANEL	10 PANELS	100 PANELS	1 PANEL	10 PANELS	100 PANELS
21.3	Set-up Time	9.90	.99	.11	6.60	.66	.07
21.3A	Cut Honeycomb	2.97	1.89	1.35			
21.4	Prime Honeycomb	1.80	.90	.68			
21.5	Mix Ablative (.5 hr)	2.16	1.35	1.08			
21.6	Weigh, Calculate	.12	.12	.12			
21.7	Measure Mix	.36	.27	.27			
21.8	Load Mold	5.40	3.24	2.97	2.70	1.62	1.48
21.9	Cure Panel (3 hrs)	.75	.60	.60	3.75	3.60	3.60
21.10	Cool & Open Mold	.30	.30	.30	.30	.30	.30
21.11	Remove Panel, Deflash & Reassemble Mold	4.32	3.24	2.97	1.00	.70	.65
21.12	Prepare Skin	1.80	1.13	.68	.60	.37	.23
21.13	Apply Skin & Clean-up	4.08	2.60	2.09	4.04	3.30	3.05
21.15	Weigh Panel & Inspect	.36	.36	.36			
21.16-21.18	Mold Plugs	1.35	.81	.81			
	Post Cure Panel(13 hrs)	2.25	1.13	1.13			
	Totals	37.92	18.93	15.52	18.99	10.55	9.38

TABLE 39

ESTIMATED HOURS FOR FABRICATION OF A
HIGH DENSITY ELASTOMERIC
3-FOOT BY 5-FOOT FLAT PANEL

OPERATION NUMBER	OPERATION DESCRIPTION	MAN-HOURS			FLOW TIME		
		1 PANEL	10 PANELS	100 PANELS	1 PANEL	10 PANELS	100 PANELS
22.3	Set-up Time	9.90	.99	.11	6.60	.66	.07
22.3A	Cut Honeycomb	2.97	1.89	1.35			
22.4	Prime Honeycomb	1.80	.90	.68			
22.5	Mix Ablative (2 hrs)	3.51	2.16	1.89			
22.6	Weigh, Calculate	.12	.12	.12			
22.7	Measure Mix	.36	.27	.27			
22.8	Load Mold	9.45	6.75	6.21	3.15	2.25	2.07
22.9	Cure Panel (2 hrs)	.75	.60	.60	2.75	2.60	2.60
22.10	Cool & Open Mold	.30	.30	.30	.30	.30	.30
22.11	Remove Panel, Deflash & Reassemble Mold	4.59	3.51	3.11	1.00	.80	.70
22.12	Prepare Skin	1.80	1.13	.68	.60	.37	.23
22.13	Apply Skin & Clean-up Panel	3.06	1.83	1.58	3.02	2.61	2.53
22.15	Weigh Panel & Inspect	.36	.36	.36			
22.16-22.18	Mold Plugs	1.35	.81	.81			
	Post Cure Panel(14 hrs)	2.25	1.13	1.13	16.25	15.13	15.13
	Totals	42.57	22.75	19.20	17.42	9.59	8.50

TABLE 40

ESTIMATED HOURS FOR FABRICATION OF A
LOW DENSITY NYLON PHENOLIC
3-FOOT BY 5-FOOT FLAT PANEL

OPERATION NUMBER	OPERATION DESCRIPTION	MAN-HOURS			FLOW TIME		
		1 PANEL	10 PANELS	100 PANELS	1 PANEL	10 PANELS	100 PANELS
23.3	Set-up Time	9.90	.99	.11	6.60	.66	.07
23.3A	Cut Honeycomb	2.97	1.89	1.35			
23.4	Prime Honeycomb	1.80	.90	.68			
23.5	Mix Ablative (.5 hr.)	2.16	1.35	1.08			
23.6	Weigh, Calculate	.12	.12	.12			
23.7	Measure Mix	.36	.27	.27			
23.8	Load Mold	5.40	3.24	2.97	1.80	1.08	.99
23.9	Prepare Skin & Apply	1.80	1.13	.90	.60	.37	.30
23.10	Cure Panel (3 hrs)	.75	.60	.60	3.75	3.60	3.60
23.11	Cool & Open Mold	.30	.30	.30	.30	.30	.30
23.12	Remove Panel, Deflash & Reassemble Mold	2.97	1.89	1.76	.99	.63	.58
23.14	Weigh Panel & Inspect	.36	.36	.36			
23.15-23.18	Mold Plugs	1.35	.81	.81			
	Post Cure Panel(13 hrs)	2.25	1.13	1.13			
	Totals	32.49	14.98	12.44	14.04	6.64	5.84

TABLE 41

ESTIMATED HOURS FOR FABRICATION OF A
LOW DENSITY ELASTOMERIC
3-FOOT BY 5-FOOT FLAT PANEL

OPERATION NUMBER	OPERATION DESCRIPTION	MAN-HOURS			FLOW TIME		
		1 PANEL	10 PANELS	100 PANELS	1 PANEL	10 PANELS	100 PANELS
24.3	Set-up Time	9.90	.99	.09	6.60	.66	.07
24.3A	Cut Honeycomb	2.97	1.89	1.35			
24.4	Prime Honeycomb	1.80	.90	.68			
24.5	Mix Ablative (2 hrs)	3.51	2.16	1.89			
24.6	Weigh, Calculate	.12	.12	.12			
24.7	Measure Mix	.36	.27	.27			
24.8	Load Mold	6.21	4.05	3.65	3.07	1.35	1.22
24.9	Prepare Skin & Apply	1.80	1.50	.90	.60	.50	.30
24.10	Cure Panel (2 hrs)	.75	.60	.60	2.75	2.60	2.60
24.11	Cool & Open Mold	.30	.30	.30	.30	.30	.30
24.12	Remove Panel, Deflash & Reassemble Mold	2.97	1.89	1.75	.99	.63	.58
24.14	Weigh Panel & Inspect	.36	.36	.36			
24.15-24.18	Mold Plugs	1.35	.81	.81			
	Post Cure Panel(14 hrs)	2.25	1.13	1.13			
	Totals	34.65	16.97	13.90	14.31	6.04	5.07

TABLE 42

ESTIMATED HOURS FOR FABRICATION OF A
HIGH DENSITY NYLON PHENOLIC
4-FOOT BY 6-FOOT FLAT PANEL

OPERATION NUMBER	OPERATION DESCRIPTION	MAN-HOURS			FLOW TIME		
		1 PANEL	10 PANELS	100 PANELS	1 PANEL	10 PANELS	100 PANELS
31.3	Set-up Time	12.30	1.23	.12	8.20	.82	.08
31.3A	Cut Honeycomb	4.95	3.15	2.25			
31.4	Prime Honeycomb	3.00	1.50	1.13			
31.5	Mix Ablative (.5 hr)	3.60	2.25	1.80			
31.6	Weigh, Calculate	.20	.20	.20			
31.7	Measure Mix	.75	.57	.57			
31.8	Load Mold	9.00	5.40	4.95	3.00	1.80	1.65
31.9	Cure Panel (3 hrs)	.75	.60	.60	3.75	3.60	3.60
31.10	Cool & Open Mold	.30	.30	.30	.30	.30	.30
31.11	Remove Panel, Deflash & Reassemble Mold	7.20	5.40	4.95	1.80	1.35	1.23
31.12	Prepare Skin	2.64	1.65	1.32	.88	.55	.44
31.13	Apply Skin & Clean-up Panel	6.24	3.81	3.03	4.08	3.27	3.01
31.15	Weigh Panel & Inspect	.90	.90	.90			
31.16-31.18	Mold Plugs	2.25	1.80	.90			
	Post Cure Panel (13 hr)	3.90	1.92	1.92			
	Totals	57.98	30.68	24.94	22.01	11.69	10.31

TABLE 43

ESTIMATED HOURS FOR FABRICATION OF A
HIGH DENSITY ELASTOMERIC
4-FOOT BY 6-FOOT FLAT PANEL

OPERATION NUMBER	OPERATION DESCRIPTION	MAN-HOURS			FLOW TIME		
		1 PANEL	10 PANELS	100 PANELS	1 PANEL	10 PANELS	100 PANELS
32.3	Set-up Time	12.30	1.23	.12	8.20	.82	.08
32.3A	Cut Honeycomb	4.95	3.15	2.25			
32.4	Prime Honeycomb	3.00	1.50	1.13			
32.5	Mix Ablative (2 hrs)	5.85	3.60	3.15			
32.6	Weigh, Calculate	.20	.20	.20			
32.7	Measure Mix	.75	.57	.57			
32.8	Load Mold	15.75	11.25	10.35	5.25	3.75	3.45
32.9	Cure Panel (2 hrs)	.75	.60	.60	2.75	2.60	2.60
32.10	Cool & Open Mold	.30	.30	.30	.30	.30	.30
32.11	Remove Panel, Deflash & Reassemble Mold	7.65	5.85	5.18	1.91	1.46	1.29
32.12	Prepare Skin	2.64	1.65	1.32	.88	.55	.44
32.13	Apply Skin & Clean-up Panel	4.68	2.64	2.25	3.56	2.88	2.75
32.15	Weigh Panel & Inspect	.90	.90	.90			
32.16-32.18	Mold Plugs	2.25	1.80	.90			
	Post Cure Panel(14 hrs)	3.90	1.92	1.92			
	Totals	65.87	37.16	31.14	22.85	12.36	10.91

TABLE 44

ESTIMATED HOURS FOR FABRICATION OF A
LOW DENSITY NYLON PHENOLIC
4-FOOT BY 6-FOOT FLAT PANEL

OPERATION NUMBER	OPERATION DESCRIPTION	MAN-HOURS			FLOW TIME		
		1 PANEL	10 PANELS	100 PANELS	1 PANEL	10 PANELS	100 PANELS
33.3	Set-up Time	12.30	1.23	.12	8.20	.82	.08
33.3A	Cut Honeycomb	4.95	3.15	2.25			
33.4	Prime Honeycomb	3.00	1.50	1.13			
33.5	Mix Ablative (.5 hr)	3.60	2.25	1.80			
33.6	Weigh, Calculate	.20	.20	.20			
33.7	Measure Mix	.60	.45	.45			
33.8	Load Mold	9.00	5.40	4.95	3.00	1.80	1.65
33.9	Prepare Skin & Apply	2.64	1.65	1.32	.88	.55	.44
33.10	Cure Panel (3 hrs)	.75	.60	.60	3.75	3.60	3.60
33.11	Cool & Open Mold	.30	.30	.30	.30	.30	.30
33.12	Remove Panel, Deflash & Reassemble Mold	4.95	3.15	2.93	1.24	.79	.73
33.14	Weigh Panel & Inspect	.60	.60	.60			
33.15-33.18	Mold Plugs	2.25	1.80	.90			
	Post Cure Panel(13 hrs)	3.30	1.59	1.59			
	Totals	48.44	23.87	19.14	17.37	7.86	6.80

TABLE 45

ESTIMATED HOURS FOR FABRICATION OF A
LOW DENSITY ELASTOMERIC
4-FOOT BY 6-FOOT FLAT PANEL

OPERATION NUMBER	OPERATION DESCRIPTION	MAN-HOURS			FLOW TIME		
		1 PANEL	10 PANELS	100 PANELS	1 PANEL	10 PANELS	100 PANELS
34.3	Set-up Time	12.30	1.23	.12	8.20	.82	.08
34.3A	Cut Honeycomb	4.95	3.15	2.25			
34.4	Prime Honeycomb	3.00	1.50	1.13			
34.5	Mix Ablative (2 hr)	5.85	3.60	3.15			
34.6	Weigh, Calculate	.20	.20	.20			
34.7	Measure Mix	.60	.45	.45			
34.8	Load Mold	10.35	6.75	6.08	3.45	2.25	2.02
34.9	Prepare Skin & Apply	2.64	1.65	1.32	.88	.55	.44
34.10	Cure Panel (2 hrs)	.75	.60	.60	2.75	2.60	2.60
34.11	Cool & Open Mold	.30	.30	.30	.30	.30	.30
34.12	Remove Panel, Deflash & Reassemble Mold	4.95	3.15	2.93	1.24	.79	.73
34.14	Weigh Panel & Inspect	.60	.60	.60			
34.15-34.18	Mold Plugs	2.25	1.80	.90			
	Post Cure Panel (14 hr)	3.30	1.59	1.59			
	Totals	52.04	26.57	21.62	16.82	7.31	6.17

BRUNSWICK CORPORATION TECHNICAL PRODUCTS DIVISION MANUFACTURING & INSPECTION RECORD	OPERATION SEQUENCE 1.0 SHEET 1 OF 3

TITLE: FLAT ABLATIVE PANEL - 50-50 MIX

OPER. SEQ. NO.	PROCESS INSTRUCTIONS
1.0	SCOPE This sequence describes the procedure for molding a 24" x 48" ablative panel using 50-50 mix.
1.1	MATERIALS

BMS	Description
BMS 10106	Honeycomb Sheet (4.5 #D)
BMS 11018	Hardener (Tonox)
BMS 11004	Epoxy Resin (Epon 828)
BMS 10108	1582 Cloth
BMS 11138	Phenolic Microballoons (BJO 0930)
BMS 11230	Phenolic Resin (BRL 1100)
BMS 11192	Powdered Phenolic Resin (BRP-5549)
BMS 11191	Powdered Nylon Resin (66D)
BMS 13100	Release Fabric
BMS 13043	Mold Release (S122)

OPER. SEQ. NO.	PROCESS INSTRUCTIONS
1.2	TOOLS AND EQUIPMENT Resin Dip Tray 200 Ton Press Steam Heated Platens for Press Ablative Panel Mold Drum Mixer
1.3	Install the heated platens in the press. Install the ablative panel mold (CM-8352001) into the mold on the heated platens. Make sure the upper and lower halves of the mold are centered in the cavity (because this mold has no guide pins) before the mold holddown bolts are tightened.

TITLE FLAT ABLATIVE PANEL - 50-50 MIX	SEQUENCE NUMBERS 1.4 - 1.9 SHEET 2 OF 3

OPER SEQ NO.	PROCESS INSTRUCTIONS
1.4	Lay honeycomb panel into the dip tray. Pour the honeycomb full of BRL 1100 phenolic resin (BMS 11230) to coat all surfaces of the cells. Remove the honeycomb from the resin and support it over the tray to drip for 20 minutes + 10 - 0 minutes. Lay the honeycomb on Kimwipes to absorb excess resin.
1.5	Make up the following mix of materials: BMS 11191 Nylon Resin 16 lbs. BMS 11192 Phenolic Resin 16 lbs. Place the nylon and phenolic resin into a clean drum. Place on rotater and rotate for 1/2 hour.
1.6	Weigh the honeycomb and record the weight here. ________ lbs. Add skin weight/primer weight allowance of 1.5 lbs. = ______ + 1.5 = ______.
1.7	Measure out an amount of the mixture made up in Oper. 2.4 equal to 36.5 lbs. less the honeycomb/skin panel weight calculated in Oper. 2.6. Calculation here: 36.5 - ________ = lbs.
1.8	Open the cold mold which is installed in the press. Put a light coat of S-122 mold release all over the mold. Put the honeycomb panel into the mold. Pour the material into the honeycomb. As material is poured in, rub the honeycomb with a Teflon squeegee. This will vibrate the cell edges and cause material to fall to bottom of cell. Screed material to form an even layer over top of honeycomb.
1.9	Close the mold to the stops and turn the steam to the steam platens to raise the mold temperature to a temperature of 300 ± 15° F. Measure the temperature on all four (4) sides of the mold with a pyrometer and when it is up to temperature, cure the part for 16 hours + 1 hour - 0 hour at this temperature. After three (3) hours, turn press off. Remainder of cure to be accomplished with press off.

TITLE FLAT ABLATIVE PANEL - 50-50 MIX	SEQUENCE NUMBERS 1.10 - 1.18 SHEET 3 OF 3

OPER SEQ NO.	PROCESS INSTRUCTIONS
1.10	Turn off the steam to the platens and turn on the cold water to cool the platens and mold. When the mold temperature has become uniform within 15^{o} on all four (4) sides and dropped below 150^{o} F., open the mold and remove the front wall panel of the mold by removing the four (4) bolts which hold it to the side walls.
1.11	Remove the panel from the mold and clean the mold. Spray mold with S-122 release. Clean the panel up and wire brush the side that was formed by the lower side of the mold. Reassemble the mold. Place the panel back into the mold with the brushed side up.
1.12	Cut a piece of cloth (BMS 10108) 24" x 48". Impregnate the cloth with 1-1/2 times the cloth weight) resin mixed per LRF-136. Epoxy Resin (BMS 11004) Epon 828 400 grams Hardener (BMS 11018) Tonox 116 grams
1.13	Mix 1.5 lbs. LRF-136. Add five (5) parts Cabosil per 100 parts resin. Apply this material to top surface of panel. Place the impregnated cloth onto the top surface of the panel. Close the press and cure for two (2) hours at 250^{o} F. Cool to 150^{o} F. maximum. Remove the front rail from the mold and remove the part. Remove flash from part by filing.
1.14	Lay out hole pattern. Drill 1/4" holes through the skin and panel. Turn the part over and drill .750 diameter holes through the ablative material to skin only. Do not drill through the skin.
1.15	Weigh the panel and record weight ____________
1.16	Spray the inside surface of the plug mold with S-122 release. Heat lab press to 300 ± 15^{o} F.
1.17	Place 4.5 grams of material mixed in Oper. 2.5 in each of the six (6) cavities. Place a pin in each of the six (6) holes. Place in heated press and close press. Cure for three (3) hours at 300 ± 15^{o} F.
1.18	Remove from mold while hot. Clean up as necessary. Cut to length.

BRUNSWICK CORPORATION TECHNICAL PRODUCTS DIVISION MANUFACTURING & INSPECTION RECORD	OPERATION SEQUENCE 2.0 SHEET 1 OF 4

TITLE: FLAT ABLATIVE PANEL - 67-33 MIX

OPER. SEQ. NO.	PROCESS INSTRUCTIONS
2.0	SCOPE This sequence describes the procedure for molding a 24" x 48" ablative panel using 67-33 mix.
2.1	MATERIALS BMS — Description BMS 10106 — Honeycomb Sheet (4.5 #D) BMS 11018 — Hardener (Tonox) BMS 11004 — Epoxy Resin (Epon 828) BMS 10108 — 1582 Cloth BMS 11138 — Phenolic Microballoons (BJO 0930) BMS 11230 — Phenolic Resin (BRL 1100) BMS 11193 — Sylgard 182 BMS 13043 — Mold Release (S-122)
2.2	TOOLS AND EQUIPMENT Resin Dip Tray 200 Ton Press Steam Heated Platens for Press Ablative Panel Mold Drum Mixer
2.3	Install the heated platens in the press. Install the ablative panel mold (CM-8352001) into the mold on the heated platens. Make sure the upper and lower halves of the mold are centered in the cavity (because this mold has no guide pins) before the mold holddown bolts are tightened.

TITLE FLAT ABLATIVE PANEL - 67-33 MIX	SEQUENCE NUMBERS 2.4 - 2.8 SHEET 2 OF 4

OPER SEQ NO.	PROCESS INSTRUCTIONS
2.4	Lay honeycomb panel into the dip tray. Pour the honeycomb full of BRL 1100 phenolic resin (BMS 11230) to coat all surfaces of the cells. Remove the honeycomb from the resin and support it over the tray to drip for 20 minutes + 10 - 0 minutes. Lay the honeycomb on Kimwipes to absorb excess resin.
2.5	Make up the following mix of materials: BMS 11138 Microballoons 10.5 lbs. BMS 11193 Sylgard 192 (mixed) 21.1 lbs. Sift dried Microballoons into a clean drum. Mix the Sylgard 1 part catalyst to 10 parts resin. Add Microballoons to the resin until the mix is thick, mixing thoroughly as they are added. Place a 1/8" mesh screen over the drum and push the mixed material through the screen into the Microballoons remaining in the drum. Place the drum onto the rotater and rotate for 1 to 2 hours.
2.6	Weigh the honeycomb panel and record the weight here. ______ lbs. Add skin and skin primer weight allowance of 1.5 lbs. = __________ + 1.5 = ___________ lbs.
2.7	Measure out an amount of the Microballoon mixture made up in Oper. 2.4 equal to 38.5 lbs. less the honeycomb/skin panel weight calculated in Oper. 2.5. Calculation here: 38.5 - __________ = lbs.
2.8	Open the cold mold which is installed in the press. Put a light coat of S-122 mold release all over the mold. Put the honeycomb panel into the mold. Place a 1/8" mesh screen on top of the honeycomb. Pour material on the screen and rub to force through the screen and allow to fall into the honeycomb cells. Continue until the cells are full. Remove the screen and place a larger screen over the mold frame. Force 1/2 of the remaining material through the screen, remove screen, and screed the material to an even layer. Close the mold

TITLE FLAT ABLATIVE PANEL - 67-33 MIX	SEQUENCE NUMBERS 2. 8 - 2.16 SHEET 3 OF 4

OPER SEQ NO.	PROCESS INSTRUCTIONS
	to force this material into the honeycomb. Replace screen and force the remaining material through screen onto the honeycomb.
2.9	Close the mold to the stops and turn the steam to the steam platens to raise the mold temperature to a temperature of 250 ± 10^{o} F. Measure the temperature on all four (4) sides of the mold with a pyrometer and when it is up to temperature, cure the part for 16 hours + 1 hour - 0 hour at this temperature. After three (3) hours, turn press off. Remainder of cure to be accomplished with press off.
2.10	Turn off the steam to the platens and turn on the cold water to cool the platens and mold. When the mold temperature has become uniform within 15^{o} on all four (4) sides and dropped below 150^{o} F. open the mold and remove the front wall panel of the mold by removing the four (4) bolts which hold it to the side walls.
2.11	Remove the panel from the mold and clean the mold. Spray mold with S-122 release. Clean the panel up and wire brush the side that was formed by the lower side of the mold. Place the panel back into the mold with the brushed side up.
2.12	Cut a piece of cloth (BMS 10108) 24" x 48". Impregnate the cloth with 1-1/2 times the cloth weight) resin mixed per LRF-136. Epoxy Resin (BMS 11004) Epon 828 400 grams Hardener (BMS 11018) Tonox 116 grams
2.13	Place the impregnated cloth onto the top surface of the panel. Close the press and cure for two (2) hours at 250^{o} F. Cool to 150^{o} F. maximum. Remove the front rail from the mold and remove the part. Remove flash from part by filing.
2.14	Lay out hole pattern. Drill 1/4" holes through the skin and panel. Turn the part over and drill .750 diameter holes through the ablative material to skin only. Do not drill through the skin.
2.15	Weigh the panel and record weight ____________
2.16	Spray the inside surface of the plug mold with S-122 release. Heat lab press to 300 ± 15^{o} F.

TITLE FLAT ABLATIVE PANEL - 67-33 MIX	SEQUENCE NUMBERS 2.17 - 2.18 SHEET 4 OF 4
OPER SEQ NO.	**PROCESS INSTRUCTIONS**
2.17	Place 4.5 grams of material mixed in Oper. 2.5 in each of the six (6) cavities. Place a pin in each of the six (6) holes. Place in heated press and close press. Cure for three (3) hours at 300 ± 15° F.
2.18	Remove from mold while hot. Clean up as necessary; cut to length.

BRUNSWICK CORPORATION TECHNICAL PRODUCTS DIVISION MANUFACTURING & INSPECTION RECORD	OPERATION SEQUENCE 3.0 SHEET 1 OF 3

TITLE: FLAT ABLATIVE PANEL - 70-15-15 MIX

OPER. SEQ. NO.	PROCESS INSTRUCTIONS
3.0	SCOPE This sequence describes the procedure for molding a 24" x 48" ablative panel using 70-15-15 mix.
3.1	MATERIALS

BMS	Description
BMS 10106	Honeycomb Sheet (2.2 #D)
BMS 11018	Hardener (Tonox)
BMS 11004	Epoxy Resin (Epon 828)
BMS 10108	1582 Cloth
BMS 11138	Phenolic Microballoons (BJO 0930)
BMS 11230	Phenolic Resin (BRL 1100)
BMS 11191	Nylon Resin
BMS 11192	Phenolic Resin
BMS 13043	Mold Release (S-122)

OPER. SEQ. NO.	PROCESS INSTRUCTIONS
3.2	TOOLS AND EQUIPMENT Resin Dip Tray 200 Ton Press Steam Heated Platens for Press Ablative Panel Mold Drum Mixer
3.3	Install the heated platens in the press. Install the ablative panel mold (CM-8352001) into the mold on the heated platens. Make sure the upper and lower halves of the mold are centered in the cavity (because this mold has no guide pins) before the mold holddown bolts are tightened.

TITLE FLAT ABLATIVE PANEL - 70-15-15 MIX	SEQUENCE NUMBERS 3.4 - 3.9 SHEET 2 OF 3

OPER SEQ NO.	PROCESS INSTRUCTIONS
3.4	Lay honeycomb panel into the dip tray. Pour the honeycomb full of BRL 1100 phenolic resin (BMS 11230) to coat all surfaces of the cells. Remove the honeycomb from the resin and support it over the tray to drip for 20 minutes + 10 - 0 minutes. Lay the honeycomb on Kimwipes to absorb excess resin.
3.5	Mkae up the following mix of materials: BMS 11138 Microballoons 12.50 lbs. BMS 11191 Nylon Resin 2.65 lbs. BMS 11192 Phenolic Resin 2.65 lbs. Put the material into the drum mixer and rotate for thirty (30) minutes.
3.6	Weigh the honeycomb panel and record the weight here. ________ lbs. Add skin and skin primer weight allowance of 1.5 lbs. = ____________ + 1.5 = ____________ lbs.
3.7	Measure out an amount of the Microballoon mixture made up in Oper. 2.4 equal to 22.0 lbs. less the honeycomb/skin panel weight calculated in Oper. 2.6. Calculation here: 22 - ____________ = lbs.
3.8	Open the cold mold which is installed in the press. Put a light coat of S-122 mold release all over the mold. Pour the material into the mold and spread evenly in mold. Place the honeycomb into the mold but <u>do not</u> push all the way down (approx. 1" below top surface of mold rim).
3.9	Cut a piece of cloth (BMS 10108) 24" x 48". Impregnate the cloth with 1-1/2 times the cloth weight) resin mixed per LRF-136. Epoxy Resin (BMS 11004) Epon 828 400 grams Hardener (BMS 11018) Tonox 116 grams Place the impregnated cloth on top of the honeycomb.

TITLE FLAT ABLATIVE PANEL - 70-15-15 MIX	SEQUENCE NUMBERS 3.10 - 3.18 SHEET 3 OF 3

OPER SEQ NO.	PROCESS INSTRUCTIONS
3.10	Close the mold to the stops and turn the steam to the steam platens to raise the mold temperature to a temperature of 300 ± 15° F. Measure the temperature on all four (4) sides of the mold with a pyrometer and when it is up to temperature, cure the part for 16 hours + 1 hour - 0 hour at this temperature. After three (3) hours, turn press off. Remainder of cure to be accomplished with press off.
3.11	Turn off the steam to the platens and turn on the cold water to cool the platens and mold. When the mold temperature has become uniform within 15° on all four (4) sides and dropped below 150° F., open the mold and remove the front wall panel of the mold by removing the four (4) bolts which hold it to the side walls.
3.12	Remove the panel from the mold and remove flash from panel. Reassemble the mold.
3.13	Lay out hole pattern. Drill 1/4" holes through the skin and panel. Turn the part over and drill .750 diameter holes through the ablative material to skin only. <u>Do</u> <u>not</u> drill through the skin.
3.14	Weigh the panel and record weight. ____________
3.15	Clean the six (6) cavity plug mold and spray the cavities with S-122 release.
3.16	Place 3 grams of the material mixed in Oper. 2.5 into each of six (6) cavities. Place the steel pins into the cavities. Place the mold into the press and close press.
3.17	Cure for three (3) hours at 300 ± 15° F.
3.18	Remove from press and remove from mold while hot. Deflash and cut to length as necessary.

BRUNSWICK CORPORATION TECHNICAL PRODUCTS DIVISION MANUFACTURING & INSPECTION RECORD	OPERATION SEQUENCE 4.0 SHEET 1 OF 3

TITLE: FLAT ABLATIVE PANEL - 80-20 MIX

OPER. SEQ. NO.	PROCESS INSTRUCTIONS
4.0	SCOPE This sequence describes the procedures for molding a 24" x 48" ablative panel using 80-20 mix.
4.1	MATERIALS BMS — Description BMS 10106 — Honeycomb Sheet (2.2 #D) BMS 11018 — Hardener (Tonox) BMS 11004 — Epoxy Resin (Epon 828) BMS 10108 — 1582 Cloth BMS 11138 — Phenolic Microballoons (BJO 0930) BMS 11230 — Phenolic Resin (BRL 1100) BMS 11193 — Sylgard 182 BMS 13043 — Mold Release
4.2	TOOLS AND EQUIPMENT Resin Dip Tray 200 Ton Press Steam Heated Platens for Press Ablative Panel Mold Drum Mixer
4.3	Install the heated platens in the press. Install the ablative panel mold (CM-8352001) into the mold on the heated platens. Make sure the upper and lower halves of the mold are centered in the cavity (because this mold has no guide pins) before the mold holddown bolts are tightened.

TITLE FLAT ABLATIVE PANEL - 80-20 MIX	SEQUENCE NUMBERS 4.4 - 4.9 SHEET 2 OF 3

OPER SEQ NO.	PROCESS INSTRUCTIONS
4.4	Lay honeycomb panel into the dip tray. Pour the honeycomb full of BRL 1100 phenolic resin (BMS 11230) to coat all surfaces of the cells. Remove the honeycomb from the resin and support it over the tray to drip for 20 minutes + 10 - 0 minutes. Lay the honeycomb on Kimwipes to absorb excess resin.
4.5	Make up the following mix of materials: BMS 11138 Microballoons 14.4 lbs. BMS 11193 Sylgard 182 (mixed) 3.6 lbs. Sift dried Microballoons into a clean drum. Mix the Sylgard 1 part catalyst to 10 parts resin. Add Microballoons to the resin until the mix is thick, mixing thoroughly as they are added. Place a 1/8" mesh screen over the drum and push the mixed material through the screen into the remaining Microballoons in the drum. Place the drum onto the rotater and rotate for 1 to 2 hours.
4.6	Weigh the honeycomb panel and record the weight here. _______lbs. Add skin and skin primer weight allowance of 1.5 lbs. = _________ + 1.5 = _________ lbs.
4.7	Measure out an amount of the Microballoon mixture made up in Oper. 2.4 equal to 22 lbs. less the honeycomb/skin panel weight calculated in Oper. 2.6. Calculation here: 22 - ___________ = lbs.
4.8	Open the cold mold which is installed in the press. Put a light coat of S-122 mold release all over the mold. Pour the material into the mold and spread evenly in mold. Place the honeycomb into the mold but do not push all way down (approx. 1" below top surface of mold rim).
4.9	Cut a piece of cloth (BMS 10108) 24" x 48". Impregnate the cloth with 1-1/2 times the cloth weight) resin mixed per LRF-136. Epoxy Resin (BMS 11004) Epon 828 400 grams Hardener (BMS 11018) Tonox 116 grams Place the impregnated cloth on top of the honeycomb.

TITLE FLAT ABLATIVE PANEL - 80-20 MIX	SEQUENCE NUMBERS 4.10 - 4.18 SHEET 3 OF 3

OPER SEQ NO.	PROCESS INSTRUCTIONS
4.10	Close the mold to the stops and turn the steam to the steam platens to raise the mold temperature to a temperature of 250 ± 10^{o} F. Measure the temperature on all four (4) sides of the mold with a pyrometer and when it is up to temperature, cure the part for 16 hours + 1 hour - 0 hour at this temperature. After three (3) hours, turn press off. Remainder of cure to be accomplished with press off.
4.11	Turn off the steam to the platens and turn on the cold water to cool the platens and mold. When the mold temperature has become uniform within 15^{o} on all four (4) sides and dropped below 150^{o} F., open the mold and remove the front wall panel of the mold by removing the four (4) bolts which hold it to the side walls.
4.12	Remove the panel from the mold and remove flash from panel. Reassemble the mold.
4.13	Lay out hole pattern. Drill 1/4" holes through the skin and panel. Turn the part over and drill .750 diameter holes through the ablative material to skin only. <u>Do</u> <u>not</u> drill through the skin.
4.14	Weigh the panel and record weight. ________________
4.15	Clean the six (6) cavity plug mold and spray the cavities with S-122 release.
4.16	Place 3 grams of the material mixed in Oper. 2.5 into each of the six (6) cavities. Place the steel pins into the cavities. Place the mold into the press and close press.
4.17	Cure for three (3) hours at 300 ± 15^{o} F.
4.18	Remove from press and remove from mold while hot. Deflash and cut to length as necessary.

BRUNSWICK CORPORATION TECHNICAL PRODUCTS DIVISION MANUFACTURING & INSPECTION RECORD	OPERATION SEQUENCE 11.0 SHEET 1 OF 5

TITLE: CURVED ABLATIVE PANEL - 50-50 MIX

OPER. SEQ. NO.	PROCESS INSTRUCTIONS
11.0	SCOPE This sequence describes the procedure for molding a curved 24" x 48" ablative panel using 50-50 mix.
11.1	MATERIALS BMS — Description 10106 — Honeycomb Sheet (2.2 #D) 11018 — Hardener (Tonox) 11004 — Epoxy Resin (Epon 828) 10003 — 1581 Cloth 11138 — Phenolic Microballoons (BJO 0930) 11230 — Phenolic Resin (BRL 1100) 11192 — Powdered Phenolic Resin (BRP-5549) 11191 — Powdered Nylon Resin (66D) 13100 — Release Fabric 12017 — Mylar Film 13043 — S-122 Release Agent
11.2	TOOLS AND EQUIPMENT Resin Dip Tray 200 Ton Press Steam Heated Platens for Press Ablative Panel Mold Honeycomb Forming Jig Drum Mixer

TITLE CURVED ABLATIVE PANEL - 50-50 MIX	SEQUENCE NUMBERS 11.3 - 11.6 SHEET 2 OF 5

OPER SEQ NO.	PROCESS INSTRUCTIONS
11.3	Cut honeycomb sheet to fit the 24" x 48" mold cavity. Splicing of honeycomb where necessary shall be accomplished using an interlocking splice. Ribbon direction shall be longitudinal with the mold. Using a Stanley knife with the blade set to penetrate 1/2 inch through the honeycomb, slash diagonally through all cells on one side of the honeycomb. Slash the same way diagonally in the other direction on the same side. Heat the honeycomb panel in the oven set at 600° F. for 20 seconds. Place it onto the rubber blanket on the honeycomb forming jig with the slashed side up (ribbon direction longitudinal with the jig) and form it immediately with the top half of the jig by pressing down into the rubber blanket (see sketch). Forming must be complete within 5 seconds of removal of the honeycomb from the oven. Hold the honeycomb in its formed state in the jig until it cools to a temperature of less than 200° F. This will take at least 10 minutes.
11.4	Install the heated platens in the press. Install the ablative panel mold (CM-8352002) into the mold on the heated platens. Make sure the upper and lower halves of the mold are centered in the cavity (because this mold has no guide pins) before the mold holddown bolts are tightened. NOTE: Mold shall be installed with the concave half of the mold on the top press platen.
11.5	Lay honeycomb panel into the dip tray. Pour the honeycomb full of BRL 1100 phenolic resin (BMS 11230) to coat all surfaces of the cells. Remove the honeycomb from the resin and support it over the tray to drip for 20 minutes + 10 - 0 minutes. Lay the honeycomb on Kimwipes to absorb excess resin.
11.6	Make up the following mix of materials: BMS 11191 Nylon Resin 16 lbs. BMS 11192 Phenolic Resin 16 lbs. Place the nylon and phenolic resin into a clean drum. Place on a rotater and rotate for 1/2 hour.

TITLE CURVED ABLATIVE PANEL - 50-50 MIX	SEQUENCE NUMBERS 11.7 - 11.10 SHEET 3 OF 5

OPER SEQ NO.	PROCESS INSTRUCTIONS
11.7	Weigh the honeycomb and record the weight here ___________ lbs. Add skin weight allowance of 1.4 lbs. = _________ + 1.4 = _____________.
11.8	Measure out an amount of the mixture made up in Oper. 11.6 equal to 35 lbs. less the honeycomb/skin panel weight calculated in Oper. 11.7. Calculation here: 35.0 = __________ = lbs.
11.9	Open the cold mold which is installed in the press. Put a light coat of S-122 mold release all over the mold. Lay a piece (21-7/8" x 48") of brown release fabric into the bottom of the mold. Put the honeycomb into the mold with the slashed side down. Pour the material into the honeycomb. As material is poured in, rub the honeycomb with a Teflon squeegee. This will vibrate the cell edges and cause material to fall to the bottom of the cells. Screed the material to form an even layer over the top of the honeycomb. Cut a piece of Mylar sprayed with S-122 to 24" x 48" and lay it over the material centrally in the mold. Close the mold and open it to check that there are no voids. Repeat as necessary to get a complete fill in all cells. Make sure there are no wrinkles in the Mylar film (if there are, replace it) and leave it on top of the material when the mold is finally closed for cure.
11.10	Close the mold to the stops and turn the steam to the steam platens to raise the mold temperature to a temperature of 300 ± 15° F. Measure the temperature on all four (4) sides of the mold with a pyrometer and when it is up to temperature, cure the part for 16 hours + 1 hour - 0 hour at this temperature. After three (3) hours, turn press off. Remainder of cure to be accomplished with press off.

TITLE CURVED ABLATIVE PANEL - 50-50 MIX	SEQUENCE NUMBERS 11.11 - 11.18 SHEET 4 OF 5

OPER SEQ NO.	PROCESS INSTRUCTIONS
11.11	Turn off the steam to the platens and turn on the cold water to cool the platens and mold. When the mold temperature has become uniform within 15° on all four (4) sides and dropped below 150° F., open the mold and remove the front wall panel of the mold by removing the four (4) bolts which hold it to the side walls.
11.12	Cut a piece of cloth (BMS 10003) 21-7/8" x 48". Impregnate the cloth with (1-1/2 times the cloth weight) resin mixed per LRF-136 on a sheet of Mylar sprayed both sides with S-122. Epoxy Resin (BMS 11004) Epon 828 400 grams Hardener (BMS 11018) Tonox 116 grams Allow this cloth to B-stage 20-24 hours at room temperature.
11.13	Place 2-ply of brown release fabric into the mold. Place the impregnated cloth into the mold with the Mylar sheet still on the underside. Mix 1.5 lbs. of Op. 1.12 resin mix. Add five (5) parts Cabosil per 100 parts resin. Apply this material to the bottom(convex) side of the mold. Lay the honeycomb/ablative mix panel into the mold on top of the cloth. Close the press and cure for 2 hours at 250° F. Remove the front wall from the mold and remove the part.
11.14	Remove the panel from the mold and remove flash from panel by filing.
11.15	Lay out hole pattern. Drill 1/4" holes through the panel and skin. Drill .750 diameter holes through the ablative material to skin only. Do not drill through the skin.
11.16	Weigh the panel and record weight. ____________
11.17	Clean the six (6) cavity plug mold and spray the cavities with S-122 release.
11.18	Place three (3) grams of the material mixed in Oper. 2.5 into each of the six (6) cavities. Place the steel pins into the cavities. Place the mold into the press and close press.

TITLE CURVED ABLATIVE PANEL - 50-50 MIX	SEQUENCE NUMBERS 11.19 - 11.20 SHEET 5 OF 5

OPER SEQ NO.	PROCESS INSTRUCTIONS
11.19	Cure for three (3) hours at 300 ± 15° F.
11.20	Remove from press and remove from mold while hot. Deflash and cut to length as necessary.

BRUNSWICK CORPORATION TECHNICAL PRODUCTS DIVISION MANUFACTURING & INSPECTION RECORD	OPERATION SEQUENCE 12.0 SHEET 1 OF 5

TITLE: CURVED ABLATIVE PANEL - 67-33 MIX

OPER. SEQ. NO.	PROCESS INSTRUCTIONS
12.0	SCOPE This sequence describes the procedure for molding a curved 24" x 48" ablative panel using 67-33 mix.
12.1	MATERIALS BMS — Description 10106 — Honeycomb Sheet (2.2 #D) 11018 — Hardener (Tonox) 11004 — Epoxy Resin (Epon 828) 10003 — 1581 Cloth 11138 — Phenolic Microballoons (BJO 0930) 11230 — Phenolic Resin (BRL 1100) 11193 — Sylgard 182 13100 — Release Fabric 13043 — S-122 Mold Release
12.2	TOOLS AND EQUIPMENT Resin Dip Tray 200 Ton Press Steam Heated Platens for Press Ablative Panel Mold Honeycomb Forming Jig Drum Mixer
12.3	Cut honeycomb sheet to fit the 24" x 48" mold cavity. Splicing of honeycomb where necessary shall be accomplished using an interlocking splice. Ribbon direction shall be longitudinal with the mold. Using a Stanley knife with the blade set to penetrate 1/2 inch through the honeycomb, slash diagonally

TITLE CURVED ABLATIVE PANEL - 67-33 MIX	SEQUENCE NUMBERS 12.3 - 12.6 SHEET 2 OF 5

OPER SEQ NO.	PROCESS INSTRUCTIONS

through all cells on one side of the honeycomb. Slash the same way diagonally in the other direction on the same side.

Heat the honeycomb panel in the oven set at 600° F. for 20 seconds. Place it onto the rubber blanket on the honeycomb forming jig with the slashed side up (ribbon direction longitudinal with the jig) and form it immediately with the top half of the jig by pressing down into the rubber blank (see sketch). Forming must be complete within 5 seconds of removal of the honeycomb from the oven. Hold the honeycomb in its formed state in the jig until it cools to a temperature of less than 200° F. This will take at least 10 minutes.

12.4 Install the heated platens in the press. Install the ablative panel mold (CM-8352001) into the mold on the heated platens. Make sure the upper and lower halves of the mold are centered in the cavity (because this mold has no guide pins) before the mold holddown bolts are tightened.

NOTE: Mold shall be installed with the concave half of the mold on the top press platen.

12.5 Lay honeycomb panel into the dip tray. Pour the honeycomb full of BRL 1100 phenolic resin (BMS 11230) to coat all surfaces of the cells. Remove the honeycomb from the resin and support it over the tray to drip for 20 minutes + 10 - 0 minutes. Lay the honeycomb on Kimwipes to absorb excess resin.

12.6 Make up the following mix of materials:

BMS 11138	Microballoons	12.54 lbs.
BMS 11193	Sylgard 182 (mixed)	25.46 lbs.

Sift dried Microballoons into a clean drum. Mix the Sylgard 1 part catalyst to 10 parts resin. Add Microballoons to the resin until the mix is thick, mixing thoroughly as they are added. Place a 1/8" mesh screen over the drum and push the mixed material through the screen into the Microballoons remaining in the drum. Place the drum onto the rotater and rotate for 1 to 2 hours until mixture becomes homogenous.

TITLE CURVED ABLATIVE PANEL - 67-33 MIX	SEQUENCE NUMBERS 12.7 - 12.10 SHEET 3 OF 5

OPER SEQ NO.	PROCESS INSTRUCTIONS
12.7	Weigh the honeycomb/skin panel and record the weight here. _____________ lbs. Add skin weight allowance of 1.4 lbs. = 1.4 + _______ = _____________ lbs.
12.8	Measure out an amount of the Microballoon mixture made up in Oper. 12.6 equal to 36.5 lbs. less the honeycomb/skin panel weight recorded in Oper. 12.7. Calculation here: 36.5 - ___________ = lbs. NOTE: Save the excess mixed material for use when the skin is applied.
12.9	Open the cold mold which is installed in the press. Put a light coat of S-122 mold release all over the mold. Put the honeycomb/panel into the mold with the slashed side down. Trim the honeycomb panel around the edges if necessary to provide approximately 1/8" gap all around the honeycomb periphery. Place a 1/8" mesh screen on top of the honeycomb. Pour material on the screen and rub to force through the screen and allow to fall into the honeycomb cells. Continue until the cells are full. Take special precaution to ensure good fill of the 1/8" gap all around the panel periphery. Remove the screen and place a larger screen over the mold frame. Force 1/2 of the remaining material through the screen, remove screen, and screed the material to an even layer. Close the mold to force this material into the honeycomb. Replace screen and force the remaining material through screen onto the honeycomb.
12.10	Close the mold to the stops and turn the steam to the steam platens to raise the mold temperature to a temperature of 250 ± 10^{o} F. Measure the temperature on all four (4) sides of the mold with a pyrometer and when it is up to temperature, cure the part for 16 hours + 1 hour - 0 hour at this temperature. After three (3) hours, turn press off. Remainder of cure to be accomplished with press off.

TITLE CURVED ABLATIVE PANEL - 67-33 MIX	SEQUENCE NUMBERS 12.11 - 12.15 SHEET 4 OF 5

OPER SEQ NO.	PROCESS INSTRUCTIONS
12.11	Turn off the steam to the platens and turn on the cold water to cool the platens and mold. When the mold temperature has become uniform with 15° on all four (4) sides and dropped below 150° F., open the mold and remove the front wall panel of the mold by removing the four (4) bolts which hold it to the side walls.
12.12	Remove the panel from the mold and clean the mold. Spray mold with S-122 release. Clean the panel up and wire brush the side that was formed by the lower side of the mold. Using not more than 1 lbs. of the previously mixed Microballoon/Sylgard 182 mix (Oper. 12.6), hand pack any voids on the wire brushed side of the panel.
12.13	Cut a piece of cloth (BMS 10108) 21-7/8" x 48". Impregnate the cloth with (1-1/2 times the cloth weight) resin mixed per LRF-136 on a sheet of Mylar sparyed both sides with S-122. Epoxy Resin (BMS 11004) Epon 828 400 grams Hardener (BMS 11018) Tonox 116 grams Allow this cloth to B-stage 20-24 hours at 70° F. (room temperature)
12.14	Place the impregnated cloth into the mold with the Mylar sheet still on its underside. Lay the honeycomb/Microballoon panel into the mold on top of the cloth. Cut 2-ply of release fabric 24" x 48" and lay on top of the panel. Close the press and cure for two (2) hours at 250° F. Cool to 150° F. maximum. Remove the front rail from the mold and remove the part. Remove flash from part by filing.
12.15	Lay out hole pattern. NOTE: Dimensions for hole location are measured along the curvature on the face of the panel. Drill 1/4" holes through the panel and skin. Drill .750 diameter holes through the ablative material to skin only. <u>Do not</u> drill through the skin.

TITLE CURVED ABLATIVE PANEL - 67-33 MIX	SEQUENCE NUMBERS 12.16 - 12.19 SHEET 5 OF 5
OPER SEQ NO.	**PROCESS INSTRUCTIONS**
12.16	Weigh the panel and record weight. ____________
12.17	Spray the inside surface of the plug mold with S-122 mold release. Heat lab press to 300 ± 15° F.
12.18	Place 4.5 grams of material mixed in Oper. 2.5 in each of the six (6) cavities. Place a pin in each of the six (6) holes. Place in heated press and close press. Cure for three (3) hours at 300 ± 15° F.
12.19	Remove from mold while hot. Clean up as necessary; cut to length.

BRUNSWICK CORPORATION TECHNICAL PRODUCTS DIVISION MANUFACTURING & INSPECTION RECORD	OPERATION SEQUENCE 13.0 SHEET 1 OF 4

TITLE: CURVED ABLATIVE PANEL - 70-15-15 MIX

OPER. SEQ. NO.	PROCESS INSTRUCTIONS
13.0	SCOPE This sequence describes the procedure for molding a 24" x 48" ablative panel using 70-15-15 mix.
13.1	MATERIALS

BMS	Description
10106	Honeycomb Sheet (2.2 #D)
11018	Hardener (Tonox)
11004	Epoxy Resin (Epon 828)
10003	1581 Cloth
11138	Phenolic Microballoons (BJO 0930)
11230	Phenolic Resin (BRL 1100)
11191	Nylon Resin
11192	Phenolic Resin
12017	Mylar Film
13043	S-122 Mold Release

OPER. SEQ. NO.	PROCESS INSTRUCTIONS
13.2	TOOLS AND EQUIPMENT Resin Dip Tray 200 Ton Press Steam Heated Platens for Press Ablative Panel Mold Honeycomb Forming Jig
13.3	Cut honeycomb sheet to fit the 24" x 48" mold cavity. Splicing of honeycomb where necessary shall be accomplished using an interlocking splice. Ribbon direction shall be longitudinal with the mold. Using a Stanley knife with the blade set to penetrate 1/2 inch through the honeycomb, slash diagonally

TITLE CURVED ABLATIVE PANEL - 70-15-15 MIX	SEQUENCE NUMBERS 13.3 - 13.7 SHEET 2 OF 4

OPER SEQ NO.	PROCESS INSTRUCTIONS
	through all cells on one side of the honeycomb. Slash the same way diagonally in the other direction on the same side. Heat the honeycomb panel in the oven set at 600° F. for 20 seconds. Place it onto the rubber blanket on the honeycomb forming jig with the slashed side up (ribbon direction longitudinal with the jig) and form it immediately with the top half of the jig by pressing down into the rubber blanket (see sketch). Forming must be complete within 5 seconds of removal of the honeycomb from the oven. Hold the honeycomb in its formed state in the jig until it cools to a temperature of less than 200° F. This will take at least 10 minutes.
13.4	Install the heated platens in the press. Install the ablative panel mold (CM-8352001) into the mold on the heated platens. Make sure the upper and lower halves of the mold are centered in the cavity (because this mold has no guide pins) before the mold holddown bolts are tightened. Mold shall be installed with the concave half of the mold on the top press platen.
13.5	Lay honeycomb panel into the dip tray. Pour the honeycomb full of BRL-1100 phenolic resin (BMS 11230) to coat all surfaces of the cells. Remove the honeycomb from the resin and support it over the tray to drip for 20 minutes + 10 - 0 minutes. Lay the honeycomb on Kimwipes to absorb excess resin.
13.6	Make up the following mix of materials: BMS 11138 Microballoons 12.50 lbs. BMS 11191 Nylon Resin 2.65 lbs. BMS 11192 Phenolic Resin 2.65 lbs. Put the material into the drum mixer and rotate for thirty (30) minutes.
13.7	Weigh the honeycomb panel and record the weight here _______ lbs. Add skin weight allowance of 1.4 lbs. _______ + 1.4 = _______.

TITLE CURVED ABLATIVE PANEL - 70-15-15 MIX	SEQUENCE NUMBERS 13.8 - 13.13 SHEET 3 OF 4

OPER SEQ NO.	PROCESS INSTRUCTIONS
13.8	Measure out an amount of the Microballoon mixture made up in Oper. 13.6 equal to 21 lbs. less the honeycomb panel weight recorded in Oper. 13.7. Calculation here: 21 - ________ = lbs.
13.9	Cut a piece of cloth (BMS 10003) 21-7/8" x 48". Impregnate the cloth with (1-1/2 times the cloth weight) resin mix defined below on a sheet of Mylar sprayed both sides with S-122 mold release. Epoxy Resin (BMS 11004) Epon 828 400 grams Hardener (BMS 11018) Tonox 116 grams Allow this cloth to B-stage 20-24 hours at room temperature.
13.10	Open the cold mold which is installed in the press. Put a light coat of S-122 mold release all over the mold. Lay the pre-impregnated cloth into the bottom of the mold with the sheet of Mylar still on the underside. Put the honeycomb into the mold with the slashed side down. Pour the material into the honeycomb. As material is poured in, rub the honeycomb with a Teflon squeegee. This will vibrate the cell edges and cause material to fall to the bottom of the cells. Screed the material to form an even layer over the top of the honeycomb.
13.11	Close the mold to the stops and turn the steam to the steam platens to raise themold temperature to a temperatureof 300 ± 15^{o} F. Measure the temperature on all four (4) sides of the mold with a pyrometer and when it is up to temperature, cure the part for 16 hours + 1 hour - 0 hour at this temperature. After three (3) hours, turn press off. Remainder of cure to be accomplished with press off.
13.12	Turn off the steam to the platens and turn on the cold water to cool the platens and mold. When the mold temperature has become uniform within 15^{o} on all four (4) sides and dropped below 150^{o} F., open the mold and remove the front wall panel of the mold by removing the four (4) bolts which hold it to the side walls.
13.13	Remove the panel from the mold and remove flash from panel.

TITLE CURVED ABLATIVE PANEL - 70-15-15 MIX	SEQUENCE NUMBERS 13.14 - 13.19 SHEET 4 OF 4

OPER SEQ NO.	PROCESS INSTRUCTIONS
13.14	Lay out hole pattern. NOTE: Dimensions for hole locations are measured along the curvature of the face of the panel. Drill 1/4" holes through the panel and skin. Drill .750 diameter holes through the ablative material to skin only. Do not drill through the skin.
13.15	Weigh the panel and record weight __________
13.16	Clean the six (6) cavity plug mold and spray the cavities. with S-122 release.
13.17	Place three (3) grams of the material mixed in Oper. 2.5 into each of the six (6) cavities. Place the steel pins into the cavities. Place the mold into the press and close press.
13.18	Cure for three (3) hours at 300 ± 15° F.
13.19	Remove from press and remove from mold while hot. Deflash and cut to length as necessary.

BRUNSWICK CORPORATION TECHNICAL PRODUCTS DIVISION MANUFACTURING & INSPECTION RECORD	OPERATION SEQUENCE 14.0 SHEET 1 OF 5

TITLE: CURVED ABLATIVE PANEL - 80-20 MIX

OPER. SEQ. NO.	PROCESS INSTRUCTIONS
14.0	SCOPE This sequence describes the procedures for molding a 24" x 48" ablative panel using 80-20 mix.
14.1	MATERIALS

BMS	Description
10106	Honeycomb Sheet (2.2 #D)
11018	Hardener (Tonox)
11004	Epoxy Resin (Epon 828)
10003	1581 Cloth
11138	Phenolic Microballoons (BJO 0930)
11230	Phenolic Resin (BRL 1100)
11193	Sylgard 182
12017	Mylar Film
13043	S-122 Mold Release

14.2 TOOLS AND EQUIPMENT

Resin Dip Tray
200 Ton Press
Steam Heated Platens for Press
Ablative Panel Mold
Honeycomb Forming Jig
Drum Mixer

TITLE CURVED ABLATIVE PANEL - 80-20 MIX	SEQUENCE NUMBERS 14.3 - 14.6 SHEET 2 OF 5

OPER SEQ NO.	PROCESS INSTRUCTIONS
14.3	Cut honeycomb sheet to fit the 24" x 48" mold cavity. Splicing of honeycomb where necessary shall be accomplished using an interlocking splice. Ribbon direction shall be longitudinal with the mold. Using a Stanley knife with the blade set to penetrate 1/2 inch through the honeycomb, slash diagonally through all cells on one side of the honeycomb. Slash the same way diagonally in the other direction on the other side. Heat the honeycomb panel in the oven set at 600° F. for 20 seconds. Place it into the rubber blanket on the honeycomb forming jig with the slashed side down (ribbon direction longitudinal with the jig) and form it immediately with the top half of the jig by pressing down into the rubber blanket (see sketch). Forming must be complete within 5 seconds of removal of the honeycomb from the oven. Hold the honeycomb in its formed state in the jig until it cools to a temperature of less than 200° F. This will take at least 10 minutes.
14.4	Install the heated platens in the press. Install the ablative panel mold (CM-8352001) into the mold on the heated platens. Make sure the upper and lower halves of the mold are centered in the cavity (because this mold has no guide pins) before the mold holddown bolts are tightened. Mold shall be installed with the concave half of the mold on the bottom press platen.
14.5	Lay honeycomb panel into the dip tray. Pour the honeycomb full of BRL 1100 phenolic resin (BMS 11230) to coat all surfaces of the cells. Remove the honeycomb from the resin and support it over the tray to drip for 20 minutes + 10 - 0 minutes. Lay the honeycomb on Kimwipes to absorb excess resin.
14.6	Make up the following mix of materials: BMS 11138 Microballoons 14.4 lbs. BMS 11193 Sylgard 182 (mixed) 3.6 lbs. Sift dried Microballoons into a clean drum. Mix the Sylgard 1 part catalyst to 10 parts resin. Add Microballoons to the resin until the mix is thick, mixing thoroughly as they are added. Place a 1/8" mesh screen over the drum and push the mixed material through the screen into the remaining Micro-balloons in the drum. Place the drum onto the rotater and

TITLE CURVED ABLATIVE PANEL - 80-20 MIX	SEQUENCE NUMBERS 14.6 - 14.10 SHEET 3 OF 5

OPER SEQ NO.	PROCESS INSTRUCTIONS
	rotate for 1 to 2 hours until mixture shows no evidence of dry Microballoons.
14.7	Weigh the honeycomb and record the weight here _________ lbs. Add skin weight allowance of 1.4 lbs. __________ + 1.4 = ______________ lbs.
14.8	Measure out an amount of the Microballoon mixture made up in Oper. 14.6 equal to 21 lbs. less the honeycomb panel weight recorded in Oper. 14.7. Calculation here: 21 - ___________ = lbs.
14 9	Cut a piece of cloth (BMS 10108) 24" x 48". Impregnate the cloth with (1-1/2 times the cloth weight) resin mixed as follows: Epoxy Resin (BMS 11004) Epon 828 400 grams Hardener (BMS 11018) Tonox 116 grams
14.10	Open the cold mold which is installed in the press. Put a light coat of S-122 mold release all over the mold. Screen a 1/4" layer of Microballoon mixture evenly over the bottom of the mold. Put the honeycomb into the mold with the slashed side down and press it down into the 1/4" thick layer of mixture. Screen the material into the honeycomb. As material is screened in, rub the honeycomb with a Teflon squeegee. This will vibrate cell edges and cause material to fall to bottom of cells. Screed the material to form an even layer over top of the honeycomb. Material along the two (2) sides of the honeycomb panel should be kept only 1/4" above the top of the honeycomb cells. Cut a piece of release fabric 48" x 21-7/8" and lay it centrally into the mold on top of the material. Close the mold and open it to check there are no voids in the fill. Repeat as necessary to get a complete fill in all cells. When fill is good, leave the release fabric off the top of the material.

TITLE CURVED ABLATIVE PANEL - 80-20 MIX	SEQUENCE NUMBERS 14.10 - 14.17 SHEET 4 OF 5

OPER SEQ NO.	PROCESS INSTRUCTIONS
	Take the prepreg cloth prepared the day before per Oper. 14.10 and remove the Mylar from one side. Leave the piece of Mylar that has release agent on it on the cloth. Lay the cloth onto the top of the mixture centered in the mold to cover the whole of the panel surface.
14.11	Close the mold to the stops and turn the steam to the steam platens to raise the mold temperature to a temperature of $250 \pm 10^{\circ}$ F. Measure the temperature on all four (4) sides of the mold with a pyrometer and when it is up to temperature, cure the part for 16 hours + 1 hour - 0 hour at this temperature. After three (3) hours, turn press off. Remainder of cure to be accomplished with press off.
14.12	Turn off the steam to the platens and turn on the cold water to cool the platens and mold. When the mold temperature has become uniform within 15° on all four (4) sides and dropped below 150° F., open the mold and remove the front wall panel of the mold by removing the four (4) bolts which hold it to the side walls.
14.13	Remove the panel from the mold and remove flash from panel. Reassemble the mold and clean ready for next panel.
14.14	Lay out hole pattern. NOTE: Dimensions for hole location are measured along the curvature on the face of the panel; i.e., on the side opposite the skin. Drill 1/4" holes through the panel and skin. Drill .750 diameter holes through the ablative material to skin only. Do not drill through the skin.
14.15	Weigh the panel and record weight __________.
14.16	Clean the six (6) cavity plug molds and spary the cavities with S-122 release.
14.17	Place three (3) grams of the material mixed in Oper. 2.5 into each of the six (6) cavities. Place the steel pins into the cavities. Place the mold into the press and close press.

TITLE CURVED ABLATIVE PANEL - 80-20 MIX	SEQUENCE NUMBERS 14.18 - 14.19 SHEET 5 OF 5
OPER SEQ NO.	**PROCESS INSTRUCTIONS**
14.18	Cure for three (3) hours at 250 ± 10° F.
14.19	Remove from press and remove from mold while hot. Deflash and cut to length as necessary.

ABSTRACT

This report describes the development and application of a low-cost compression molding process for replaceable ablative panels for space shuttles. Flat and curved panels of four different ablative compositions were fabricated. The report presents detailed fabrication procedures, material costs, fabrication hours for all processes, costs of fabricated panels, and estimated costs for various panel sizes, shapes and quantities.